COM814: Project 2015 - 2016

Dissertation

School of Computing & Information Engineering

Clear Skies

Supervisor Dr Giuseppe Trombino

Second Marker Dr Patrick Corr

Submitted 31st August 2016

Ulster University

Table of Contents

Plagiarism Statement **4**

Ethical Considerations **4**

Acknowledgements **4**

Abbreviations **5**

List of Figures **6**

Abstract **8**

Introduction **9**

1.1 Introduction 9

1.2 Problem Statement 9

1.3 Aim 10

1.4 Objectives 10

1.5 Hardware and Software Requirements for Development 11

1.6 Summary 11

Analysis **12**

2.1 Introduction 12

2.2 Prevalence of Cloudy Skies 12

2.3 Light Pollution 14

2.4 Astronomy Resources 15

2.4.1 Existing Data Resources 16

2.5 Weather Resources 19

2.5.1 Weather API 19

2.6 Ubiquitous Applications 19

2.7 Professional Issues 21

2.7.1 Business Plan 21

2.7.2 The Current Market 22

2.7.3 Key Findings 23

2.8 Project Management 23

2.8.1 Methodology 23

2.8.2 Version Control 24

2.8 Architecture 24

2.10 Conclusions 25
2.10.1 Simplicity 25
2.10.2 Third Party API Resources 25
2.10.3 Mobile 27
Requirements Analysis 29
3.1 Functional Requirements 29
3.2 Non-functional Requirements 29
3.3 Summary 30
Design 31
4.1 Introduction 31
4.2 Minimum Viable Prototype 31
4.3 Open Source 32
4.4 Hardware 32
4.5 Native or Hybrid Mobile Development 33
4.5 Graphical User Interface Design 34
4.4.1 The Main User Interface 36
4.4.2 The Settings User Interface 41
4.4.3 The Alert Notification 43
4.4.4 Colour Scheme, Imagery and Font 44
4.4.5 List View Information 45
4.5 Architecture 45
4.5.1 Location 46
4.5.2 Checking Time 47
4.6 Location Services 48
4.7 API Queries 48
4.7.1 Astronomy 48
4.7.2 Weather 49
4.7.2 Aurora 51
4.7.3 ISS 53
Implementation 55
5.1 Introduction 55
5.2 System Overview 55
5.2.1 Minimum and Target SDK 55

5.2.2 Structure 55
5.3 Mobile IDE and Platform Specialization 56
5.4 Location 56
5.4.1 Latitude and Longitude Within Bounds 57
5.5 APIs 58
5.5.1 Network Connections 58
5.5.3 Downloading Files 58
5.5.4 Parsing Data 59
5.6 Key Functionality 59
5.6.1 Alarm Manager 59
5.6.2 Intent Service 59
5.6.3 Broadcast Receiver 60
5.6.4 Default Shared Preferences 60
5.6.5 Time 61
5.7 Updating the UI 61
5.8 Activity Lifecycle and Killing Apps 61
5.8.1 Coding for Battery Life 62
5.8.2 Managing Network Usage 62
5.9 Conclusions 63
Testing and Evaluation 64
6.1 Introduction 64
6.2 Testing 64
6.2.1 Verification 64
6.2.2 Validation 68
6.3 Evaluation 70
Conclusions and Recommendations 74
7.1 Key Findings 74
7.2 Future Development 75
7.2.1 Wider Release 76
References 77
Imagery 83
Appendices 84

Plagiarism Statement

I declare that this is my own work and that any material I have referred to has been accurately and consistently referenced. I have read the University's policy on plagiarism and understand the definition of plagiarism as given in the Project Handbook If it is shown that material has been plagiarised, or I have otherwise attempted to obtain an unfair advantage for myself or others, I understand that I may face sanctions in accordance with the policies and procedures of the University. A mark of zero may be awarded and the reason for that mark will be recorded on my file.

Ethical Considerations

The University Ethics Committee has classified this project as category Z.

Acknowledgements

I would like to thank my supervisor, Dr Giuseppe Trombino, for his support, guidance and feedback throughout the project. I would also like to thank my second marker, Dr Patrick Corr, along with the focus group participants who volunteered their time and insight. I would also like to thank all of the lecturers who have assisted me throughout the academic year. Finally I would like to thank my family and my partner John for their patience and support over the last year.

Abbreviations

NIAAS	Northern Ireland Amateur Astronomy Society
VO	Virtual Observatory
NASA	National Aeronautics and Space Administration
EVO	European Virtual Observatory
IVOA	International Virtual Observatory Alliance
API	Application Programming Interface
App	Application
CPU	Central Processing Unit
CTO	Chief Technical Officer
FCM	Firebase Cloud Messaging
GCM	Google Cloud Messaging
GUI	Graphical User Interface
iOS	The operating system for Apple mobile hardware
ISS	International Space Station
LBS	Location Based Services
MVC	Model View Controller
UI	User Interface
UML	Unified Modelling Language

List of Figures

Figure 1 Distance travelled to avoid light pollution. Source: Clear Skies Mobile Application Research Questionnaire Results (Appendix B).

Figure 2 Notice required before a celestial event. Source: Clear Skies Mobile Application Research Questionnaire Results (Appendix B).

Figure 3 Global Mobile Devices and Connections Growth, Cisco 2016

Figure 4 Use of mobile apps as an astronomy resource. Source: Clear Skies Mobile Application Research Questionnaire Results (Appendix B).

Figure 5 Early Clear Skies User interface design (Alert Notification)

Figure 6 ListView functionality visualisation

Figure 7 Main UI Wireframes with ListView Layouts

Figure 8 Defining List Views

Figure 9 Clear Skies Main UI Screenshots

Figure 10 Settings UI Wireframes

Figure 11 Clear Skies Settings UI Screenshots

Figure 12 Clear Skies Notification Screenshot

Figure 13 Clear Skies Architecture Design Visualisation

Figure 14 Clear Skies Algorithm: Coordinates within UK

Figure 15 Forecast.io API Call (JSON)

Figure 16 Clear Skies Algorithm: Weather Traffic Light System

Figure 17 AuroraWatch API Call (XML)

Figure 18 Clear Skies Algorithm: Likelihood of a Visible Aurora

Figure 19 Open Notify API Call (JSON)

Figure 20 Clear Skies Algorithm: ISS Night Passover

Figure 21 Changing the Checking Time

Figure 22 Clicking the Refresh button

Figure 23 Forced Weather Success

Figure 24 Open Notify fails to return data

Figure 25 AuroraWatch Red Alert

Abstract

Natural sky phenomena are difficult to view in the UK due to clouds. To assist astronomy observers, a useful tool would notify them of the visibility of natural astronomical phenomena when visibility is optimal. The Clear Skies prototype is a mobile application (or app) that combines the location of the user with weather and astronomy-related information provided by third party Application Programming Interface (API) resources. The returned data is evaluated by the application. On the occasion of a successful result, the user receives an alert notification. The notification identifies the celestial event and the forecasted optimal viewing conditions. The service as described is carried out as networked background work on a daily basis at a time selected by the user. The user also decides which of the available celestial events to check for.

The Clear Skies prototype has been developed in view of a number of key outcomes generated by the project research. There exists an extensive and wide-ranging array of freely available information on astronomy. Market research of both web and mobile-based applications reveals a propensity toward sophisticated and detailed interfaces that often simulate the night-sky viewing experience. Celestial events are included on an ad-hoc basis but the provision is not comprehensive on any one application. As a result the amateur observer often references a number of sources in order to access all of the information that they require.

The main function of the Clear Skies application is to provide users with a positive, accessible and unmediated experience of celestial events as they happen outdoors. It does this by providing the user with the key information required to achieve this, at a time when it is pragmatic to receive it.

Development has been informed by concepts associated with ubiquitous computing. The final prototype provides a scalable framework that exploits existing, reliable third party data resources and combines them to provide a simple access point for users that is unobtrusive and reliable.

Introduction

1.1 Introduction

Amateur astronomers have been studying the skies for centuries, often with great success. They have been credited with the discovery of many astronomical phenomena, among them comets, moons and double stars. William Herschel, who discovered Uranus in 1781, was an amateur (albeit very wealthy) astronomer. In more recent times, scientists were able to successfully predict the place of impact of a meteor using information gathered from amateur astronomers as it was sighted over north Sudan. This was important because it led to scientists eventually finding the small meteorites in a very sparsely populated part of the desert area (Knapen 2011). The Royal Astronomical Society remarks:

> *"It [astronomy] is one of the few sciences where amateurs make genuine contributions to research, but many observers simply do it for the excitement of seeing with their own eyes the planets, star clusters, nebulae and so on that are familiar from books."*

There are myriad astronomy resources available to the amateur astronomer. Web-based and mobile applications are numerous, as well as books and magazines, learning aids such as Planisphere and TV programmes like BBC Stargazing Live. There are also dedicated resources such as the Armagh Observatory and Planetarium and in Northern Ireland alone the Dark Sky sites at Oxford Island and Carrick-a-rede where the Milky Way is visible to the naked eye (Dark Sky Discovery n.d.). A variety of amateur clubs and societies provide support and guidance to a very healthy and engaged amateur scene. It is clear that the participants of that scene are not lacking in resources, so why create another?

1.2 Problem Statement

Natural sky phenomena are difficult to view in the UK due to clouds. To assist astronomy observers, a useful tool would notify them of the visibility of natural astronomical phenomena when visibility is optimal.

1.3 Aim

To develop a mobile application that uses the device coordinates to determine on a daily basis whether there are visible celestial events in the night sky that night. If there are visible events, the application determines whether the night sky is likely to be clear for the user to see them. If both visible event and weather results are positive, a notification alerting the user to this is raised on the device.

Celestial events are seasonal and sporadic, often occurring at short notice. Examples include comets, meteor showers and the aurora borealis.

Originally the scope of this project was limited to Northern Ireland, but as a result of the research the scope of the project was extended to the whole of the UK.

1.4 Objectives

Thorough review and analysis of research to ensure a robust understanding of the factors that impact night observing.

Research into existing astronomy-based mobile applications and consideration of their strengths and weaknesses.

Gather insight and opinion via a group of amateur astronomers from the Northern Ireland Amateur Astronomy Society (NIAAS) to help understand better their priorities, interests and preferences.

Develop a functioning prototype application that checks daily at the user's preferred time for suitable weather conditions, the likelihood of a visible aurora and the trajectory of the International Space Station (ISS) that night.

Use third party data sources to obtain astronomy and weather-related information and offer the prototype as a proof of concept of this approach.

Supply the prototype to a variety of users (including willing participants from the NIAAS focus group) for black box testing. Seek their feedback on functional requirements in order to inform future development of the application.

1.5 Hardware and Software Requirements for Development

No hardware or software was purchased in order to fulfil the objectives of the project. The following assets were used to facilitate the development of the application:

A computer capable of running Android Studio, the free Java IDE software provided by Google for Android development.

A mobile Android device for development and testing.

Java to program for Android.

Git and GitHub for the provision of version control and dissemination of the developing project respectively.

Working knowledge of Android Studio, Android Developer Tools and Practices and the unique considerations applicable developing for mobile.

1.6 Summary

The Clear Skies application demonstrates a prototype mobile software solution that alerts users to visible celestial events in their area by using their device coordinates and existing third party API resources. A simple UI and alert notifications are used to provide pertinent information to the user. This document outlines in detail the process that was followed and the justification made for decisions along the way.

Analysis

2.1 Introduction

A literature review reveals key factors that impact upon night sky observation in the UK, namely cloudy skies and light pollution. The analysis also explores the themes of astronomy and mobile technology in an industry context.

A Google Cardboard hackathon at Kainos offices in Belfast, Northern Ireland on the 19th December 2015 provided the opportunity to consider virtual reality in the context of astronomy. In principle it appeared to be a good match. Participating in the hackathon provided valuable feedback from which it was possible to gain many insights that have contributed to the project.

Feedback provided by a group of amateur astronomers has also been invaluable to the project. The NIAAS was contacted with a view to attending their monthly meeting at Ballyclare High School in Ballyclare, Northern Ireland on the 4th January 2016. After successful contact with the organisers, a research questionnaire (Appendix A) was formulated and distributed to interested members. Of the fifteen questionnaires that were returned, seven of the participants were beginner observers, four were intermediate observers, three were interested in the subject of astronomy but had never pursued it and one was an experienced observer. Although age and sex data was not collected as part of the questionnaire, the wide range of ages from children to young adult to middle-aged and retired was noted, as well as the relatively even mix of male and female (ultimately more male than female). This broad spectrum in terms of ability, age and sex contributed to the value of the information provided by the questionnaires. The results are detailed in Appendix B and C of this report.

A business case is outlined in this chapter and includes a review of currently available mobile astronomy-based applications.

2.2 Prevalence of Cloudy Skies

Two of the main requirements for successful night sky observing are clear and dark skies (Douglass 2015). Regardless of location, cloud cover can mask what is visible in

the night sky, and inevitably frustrate and demotivate observers. Many will have travelled to dark sites to avoid light pollution and braved the elements, made worse if they have journeyed in the pursuit of a particular short-lived celestial event.

In the UK where cloud cover prevails, when group events are organised, the presence of clear skies to view them are always noteworthy (Solar Eclipse, Jupiter watch and Stargazing live at Queen's 2015).

Research undertaken in the period between 1960 and 1969 at Newton Mearns, a town just outside Glasgow, Scotland evidenced that:

1. *Nights are more likely to be cloudy than clear.*
2. *There is a higher probability of cloud cover in in late summer.*
3. *A period of observable weather has less persistence than a period of cloud cover.*
4. *An observer should go operational immediately the cloud cover breaks, and persist in his work as the available window is likely to be short-lived.*

(Livesey 1971)

In the mid-1900s a group of young astronomers established radio astronomy (the study of celestial objects at radio frequencies) in Britain, which has been noted by the Royal Astronomical Society as "… a subject of observational astronomy suited to its cloudy skies" (Royal Astronomical Society n.d.).

Pallé and Butler (2001) refer to gradually increasing cloud levels over Ireland since the late 19th century and Butler, García Suárez, Coughlin and Morrell (2005) assert that the gradual decline in daily temperature range over the same period would also be consistent with such an increase in cloudiness.

Climate change is increasing the amount of cloud cover globally. Professor Gerry Gilmore of Cambridge University has asserted that by 2050 it is unlikely that ground-based telescopes will be relevant due to a combination of climate change and aeroplane traffic, which can create cloud-like deposits in the sky (Rincon 2006).

2.3 Light Pollution

Light pollution is another factor that greatly affects night observing. It is associated with the disappearance of the casual observer's view of the stars and Milky Way; with the suggestion that the exploration and discovery of the night skies has become something individuals associate with photography or a planetarium rather than with the outdoors (Crawford 2000).

With the introduction of LED street lighting, it is likely that cities will become brighter, creating more light pollution with the absence of clouds (Kyba, Ruhtz, Fischer and Hölker 2012). Pilot schemes implementing LED street lighting in the UK are already underway (Northern Ireland Executive 2015). A chance view of a celestial event in the city is becoming less and less likely and our relationship with astronomy arguably more and more abstract (Crawford 2000).

Light pollution is avoidable to varying degrees, but can require the observer to travel outside of the city in order to get a good view of the objects in the night sky. Of the fifteen people surveyed at the NIAAS meeting, 20% travel less than a mile to avoid light pollution, while approximately 46% travel 10 miles or more.

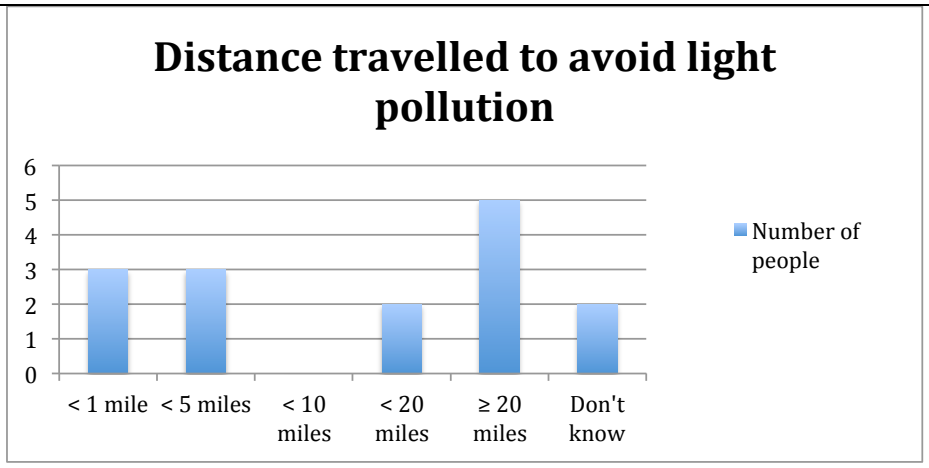


Figure 1: *Distance travelled to avoid light pollution. Source: Clear Skies Mobile Application Research Questionnaire Results (Appendix B).*

This need to travel is reflected in the advance notification time required before a celestial event. Most of those surveyed requested notification from two hours in advance of the event.

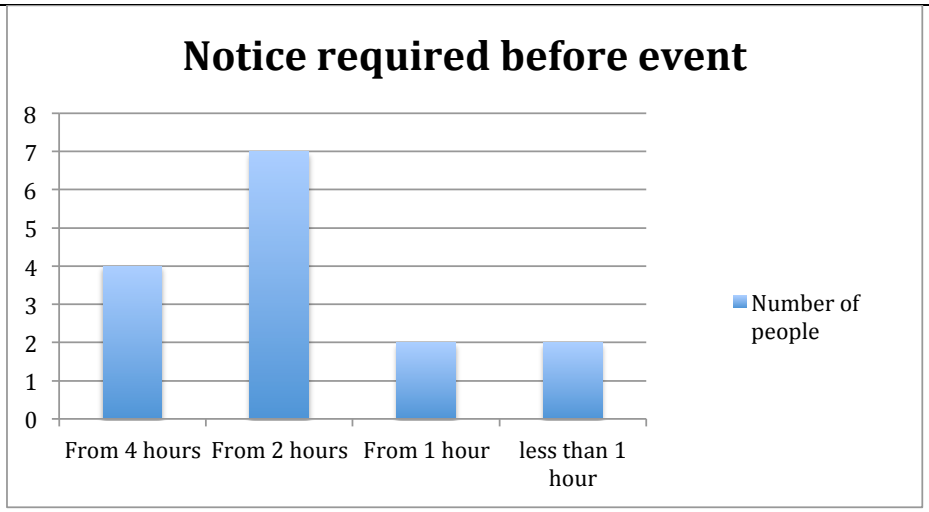


Figure 2: *Notice required before a celestial event. Source: Clear Skies Mobile Application Research Questionnaire Results (Appendix B).*

2.4 Astronomy Resources

A wide variety of astronomical resources are available to the amateur observer, often covering differing topics to different levels of detail. The British Astronomical Association's suggested web links for information on Astronomy give an indication of the wealth of resources available. It is noted also that Amazon has approximately 57,000 books on astronomy (Harvey 2015). A quick search of the Google Play website reveals hundreds of astronomy-related apps.

When the aim is simply to know when to go outside to view celestial events, too much information can make it more difficult to be informed. The endeavour can be perceived as intimidating or confusing and is therefore not pursued, or with so much information in so many different places, that which is relevant can simply be overlooked, misunderstood or misplaced. It can take time to review and get to know the merits of each source, and when more than one source is required it can take time to stay up to date with each of them.

2.4.1 Existing Data Resources

There are a large number of freely available databases online that offer information collected by national-level space organisations all over the world. Providers of this information include National Aeronautics and Space Administration (NASA) and the European Space Agency. The Centre de Données astronomiques de Strasbourg is one of a number of organisations that works with global space agencies in an effort to bring all of this information together. Government space projects host data under exciting names like SPICE and SIMBAD and open-source projects such as Stellarium and GoogleSky allow access to their source code.

Between 2001 and 2010 the UK undertook a Virtual Observatory (VO) Development project called AstroGrid. The premise behind the VO was that the world's astronomical data should be transparently useable, in just the same way that the internet makes information all over the world feel part of one giant interlinking system. The project recognised that due to the sheer (growing) volume of astronomical data it was becoming increasingly difficult to actually access it. The project also noted that the continuing development of Internet technologies such as REST made projects such as the Virtual Observatory “a feasible ideal” (Astrogrid 2012). Today the project takes the form of the European VO (EVO) and the International VO Alliance (IVOA).

Appendix D displays a list of publically available astronomy-based Application Programming Interfaces (APIs) that have been uncovered through project research to date.

The fact that an API is available online, does not necessarily mean that it will be without challenges and surprises to use. NASA’s annual Space Apps Challenge saw more than 900 application submissions in 2015, but only around a dozen of those entries that utilised NASA’s APIs. In the past they have been branded “unwieldy” (Boyd, M. 2015).

Although NASA, for example, makes available significant amounts of data online, the data itself requires treatment and analysis to provide meaningful results. Initially this provided a significant risk to the project given the short timescale. Further research

uncovered a number of projects that focus specifically on making the data more accessible to both developers and non-developers alike.

The International Space Apps Challenge is organised by NASA on a yearly basis and seeks to engage software developers with a goal to produce open-source solutions that address global needs applicable to Earth and Space.

Predict The Sky[1] is an open-source API project, which was born out of the first International Space Apps Challenge in the UK in 2012. The API combines weather data and a comprehensive library of space events but at the time of writing this report the API is still under construction. It demonstrated other developers interest in the concept and led to further research in this area.

Built in 2014, SkyWatch[2] is also the result of a NASA space apps event. In response to the challenge to create a central place for information and visualizations of sky phenomena. a real-time feed of the universe was developed. In April of this year, API access to this resource became available. SkyWatch founder James Slifierz explained their mission. "We like to see ourselves as indexing space in the way that Google indexed the Internet. We want to leverage their knowledge about how to handle massive amounts of data." (Llewellyn 2015).

At the time of writing, SkyWatch offers real-time celestial event notifications via email. These notifications are sent irrespective of time of day or weather conditions. Event descriptions can appear cryptic to the uninitiated:

GRB 160821B: Swift/UVOT Upper Limits

Detection Time: 12:46:33 UTC (2016-08-22)

A link to the web application provides the user with more information on the event, but again to the uninitiated the information can be confusing. Email notifications are regular, often reaching between six and eight daily.

---

[1] www.predictthesky.org

[2] https://app.skywatch.co/

Lancaster University in England provides an alert system that notifies users of the likelihood of a visible aurora. AuroraWatch[3] provides alert notifications via Twitter, Facebook, Email and Text. The data is in real-time - it is very difficult to accurately predict a natural event such as the aurora borealis. The notifications are automated and if a change in geomagnetic activity (the key indicator used) is detected, the subscriber is sent an alert. This can mean that a user receives notifications during the day and weather conditions are not taken into account. The notifications follow a traffic light system that clearly informs the user of the change. If the user requires more detailed information, they can access it via the AuroraWatch website. A number of developers have created apps using the AuroraWatch API. Those referenced on the AuroraWatch website provide detailed results to users and the applications focus on aurora alerts specifically.

Open Notify[4] is described by its creator Nathan Bergey as:

> "… an open source project to provide a simple programming interface for some of NASA's awesome data. I do some of the work to take raw data and turn them into APIs related to space and spacecraft."

A developer can access the International Space Station pass-over times of a given location via a simple JSON query to the Open Notify API. This resource has been cross-referenced against the NASA Spot the Station project[5] and results have been consistent.N2YO[6] offers live real time satellite tracking and predictions. In addition to its web interface, the service offers access to an API via a SOAP interface. It is managed by ITPROSTAR, an IT company based in Washington DC, who provide API access to geospatial data.

---

[3] http://aurorawatch.lancs.ac.uk

[4] http://open-notify.org

[5] https://spotthestation.nasa.gov/

[6] http://www.n2yo.com

2.5 Weather Resources

As regards the weather query, understanding the weather conditions affecting Clear Skies is important. The timing of the query is also important, as weather forecasts become more accurate the closer to the event. Other influencing factors such as the moon phase should also be considered in the final Clear Skies notification.

2.5.1 Weather API

"Weather has become a pretty hot topic, especially in technology circles" (Wagner 2014). This may in part explain the variety of weather APIs available. Appendix E details research undertaken on four different APIs, all of which were listed as among ProgrammableWeb's Top 10 Weather APIs (Wagner, J, 2014) and three of which, Wunderground.com, Forecast.io and WorldWeatherOnline.com were discussed as part of an in-depth analysis of the most popular weather platforms and APIs in use (Wagner, J, 2015).

2.6 Ubiquitous Applications

In his paper "The Computer for the 21st Century", Weiser imagines the future of mobile computing:

> "Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as taking a walk in the woods"

(Weiser 1999)

He describes disappearing technology that weaves itself into the fabric of everyday life, in part by understanding its daily rhythms. Weiser focuses on transmitting and displaying information more directly. The technology doesn't require active attention often, just a glance. Critically important is location, the computer should be aware of its surroundings and adapt itself accordingly. He also refers to virtual reality, asserting that it excludes the infinite richness of the universe. It excludes real life by simulating rather than visually enhancing what already exists.

In more recent times, at this year's Turing Lecture, "The Internet of Me: Its all about my screens" (Institution of Engineering and Technology n.d.), Robert Schukai focuses

on the future – how seamless two-way interaction with ubiquitous mobile devices will become the daily norm.

It is predicted that smartphone users in the UK will reach about 44.9 million by 2017 (Statista 2016). With the UK population in 2017 predicted at 65.2 million (Rogers 2009), the statistics suggest that by next year just under 70% of people in England, Scotland, Wales and Northern Ireland will be using smart phone technology.

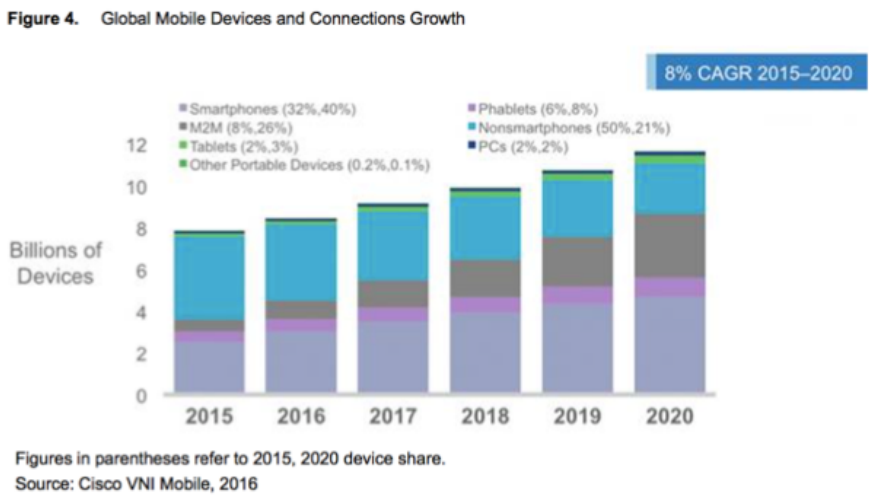


Figure 3: *Global Mobile Devices and Connections Growth, Cisco 2016*

From the NIAAS questionnaire results 46% of those surveyed stated that they regularly use a mobile to explore the night skies. 73% stated that they occasionally or regularly use a mobile app to explore the night skies.

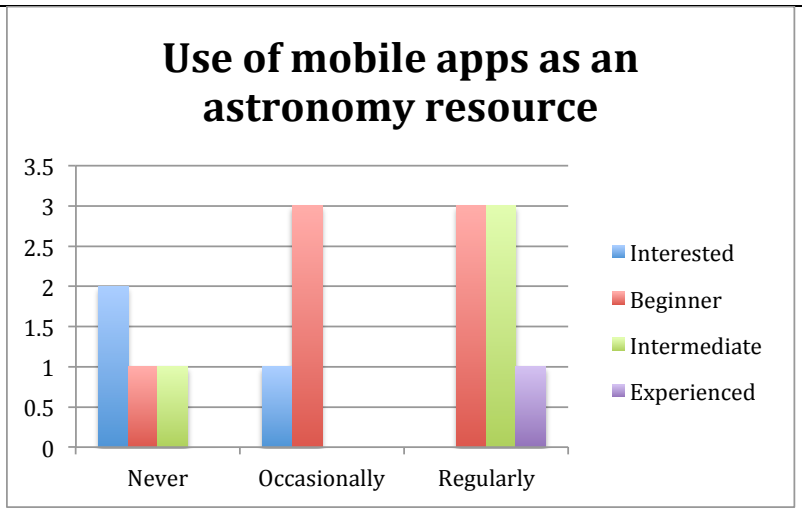


Figure 4: *Use of mobile apps as an astronomy resource. Source: Clear Skies Mobile Application Research Questionnaire Results (Appendix B).*

A mobile device with GPS hardware provides ensures that regardless of where the user is in the UK, as long as they have Internet they can receive Clear Skies alert notifications based on their GPS coordinates. This increases the possibility to take advantage of viewing opportunities as they arise, and adds an air of spontaneity to the activity. Furthermore it allows notifications to be provided within relatively short time frames, improving the accuracy of the weather forecasting.

Wearable technology is a burgeoning market that provides further potential scalability for the Clear Skies app. is built around rich notifications, which provide the user pertinent information despite a limited interface.

2.7 Professional Issues

The project is built using existing open-source software and freely available data. The aim is to support all levels of astronomy observer and provide a meaningful contribution to the astronomy community as a whole.

2.7.1 Business Plan

At the Google Cardboard Hackathon Tim Gray, the Chief Technical Officer (CTO) at Kainos referred to the current relevance of astronomy and its economic potential in

Northern Ireland and the rest of the UK. Given the minimal amount of funding required to deliver the project, it is possible that when considering the overall benefit of the Clear Skies app that one of the many parties who have a vested interest in space science may consider funding the venture. Focussing on Northern Ireland as an example, The Armagh Planetarium's mission statement is "To advance and promote the knowledge and understanding of astronomy and related sciences" (Armagh Planetarium n.d.). As of April 2016 they offer an app called PocketSky, which is only available on the iOS platform. The Armagh Planetarium was also the main advisory party behind a recent GCSE level qualification centred on Space Science Technology[7]– the first of its kind in the UK. They, along with Invest NI and other special interest groups are taking steps to develop an engaged and qualified workforce that will allow NI to take advantage of the opportunities afforded by the space economy, an industry predicted to be worth £40 billion by 2030 (McKevitt 2013). The Clear Skies app would act as a useful resource to accompany this plan.

2.7.2 The Current Market

The market research undertaken for this report is based on the NIAAS questionnaire results (Appendix B). It is comprised of mobile apps recommended by members who occasionally or regularly use mobile applications as a resource for observing the night sky. The recommended resources and their resulting analysis are detailed in appendix E.

The rationale that informed the research criteria is summarised as follows:

- Mobile applications were researched because the Clear Skies app will be mobile.
- iOS and/ or Android compatible were considered to get an idea of market share.
- Cost and in-app purchases recorded as an indication of reach and accessibility of content.

[7] http://www.rewardinglearning.org.uk/microsites/space_science_technology/

- Instances of notifications similar to those that the Clear Skies app will provide (location specific notification of upcoming celestial events and favourable weather conditions for observing).

2.7.3 Key Findings

Of the eight apps considered, five of them are not free of charge. Night Sky and Star Walk offer free versions with in-app purchases but less content (including no celestial event notifications). In the pay-for category, both of these apps also offer smart watch versions. The only app that provides both clear skies weather information and celestial event information is the Night Sky app, which costs £0.99. All of the apps provide a wide variety of functions and information about astronomy. The content and functionality provided is often found to be overlapping between apps.

2.8 Project Management

2.8.1 Methodology

As is the case with many real-world projects, the developer is not an expert in the project domain, the technology resources available are evolving and requirement changes are likely to occur within the project lifecycle. The agile development framework has been chosen because it will be necessary to adapt quickly in order to respond to those changing requirements and deliver a working prototype within the short timeframe allowed. The lightweight framework focuses on the value of individuals over interactions, working software, customer collaboration and responding to change (Beck et al. 2001).

Agile methodologies such as Scrum and XP are not an ideal fit for this project. Scrum requires specific roles and activities that cannot be filled by a one-person team and XP relies heavily on the contribution of the user perspective, which is not realistic in terms of this specific project (Bowes 2015). Kanban is appealing in terms of the clarity it offers around bottlenecks in the project. However given the size of this project, it is deemed unnecessary (Bowes 2015). Although a specific methodology will not be implemented for the project, it will seek to embody the ethos of the agile

framework. User stories inform development. They form the basis of the product backlog and, depending on priority and complexity, define sprints and releases. It has been determined that a test driven approach to development would be overhead-heavy but both unit and integration testing will play an integral role in the design process. System and acceptance testing will also form a vital part of the development lifecycle. Microsoft asserts in their Visual Studio documentation that "catching defects as early as possible is the least expensive way to ensure software quality" (Microsoft Visual Studio 2012, n.d.).

2.8.2 Version Control

In terms of version control, Git has been chosen for a number of reasons. It has been recommended in tutorials (Udacity, How to Use Git and GitHub, n.d.) and from using the tutorials to try out the software, it has proved to be reasonably straightforward at both the command line and within Android Studio. Although it is unlikely that all of the functionality of Git will be of benefit to the project before its first release, many advantages of the distributed model and the support it offers teams align with the project's focus on scalability and building a foundation for future development. By using GitHub for backups, the versions stored in the cloud are available to any other parties who are interested in the project. This is important given the project's own reliance upon existing open-source and other publically available resources.

2.8 Architecture

The prescriptive architectural design of the project will be in the form of Unified Modelling Language (UML). The aim of this approach is to ensure that the architecture is implemented as it is conceived. Changes to the architecture will be made prescriptively, allowing them to be considered in terms of the whole project, before any code is amended.

By approaching the project in an object-orientated fashion, data takes precedence over functions of the code. Incorporating the principles of inheritance and information hiding limits the effects of changes, which in turn reduces maintenance costs and makes updating and scaling up the software easier. By enforcing good

design it is possible to create modular, reusable code that is based on real-world entities (Udacity, Software Development Process, n.d.).

It is important to establish this design framework if the project is to fulfil its objective to be scalable. The API landscape is evolving and national-level interest in astronomy is increasing on a daily basis.

2.10 Conclusions

2.10.1 Simplicity

In order to combat the difficulties a vast array of information and its wide-ranging and varied sources present, a simple interface provides a potential solution. The power in this app comes from the fact that its content is largely invisible to the user. It is only when an alert notification is triggered that the user is informed of the presence of a celestial event of interest coupled with clear and dark skies. The notification provides enough time to prepare to enjoy the event outside, in its natural habitat. No research or cross-referencing of information is required. There is no complicated or extensive interface to get lost in. In the same way that Google's search engine provides a very simple interface with a very powerful backend (Maeda 2006 p. iv) the Clear Skies app aims to offer a similar simple design that provides valuable results in a clear and concise fashion. Its accessibility will encourage and facilitate amateur astronomy in a geographical area often impacted by unsuitable weather conditions. Rather than viewing astronomical phenomena in a virtual reality setting or by way of a photographic image as offered by other astronomy apps such as Stellarium Mobile Sky or Heavens Above, the user is encouraged to connect people to the universe outside and experience the satisfaction of seeing these events live in the night sky. Furthermore, they can participate in the ground-based campaigns (European Space Agency n.d.) that are so valuable to the field of astronomy and maintain the beneficial reciprocity arrangement that has existed between professional and amateur astronomers for hundreds of years.

2.10.2 Third Party API Resources

APIs provide a standardised interface for consumers (Berlind 2015). From an astronomy perspective, using a dedicated API Portal, NASA are trying to meet the

White House Mandate to make freely available the data that they hold, in a format that is widely accessible (Nasa APIs n.d.). In their digital strategy they make clear their intention to “make existing high-value data and content available through web APIs” (Herron 2012).

Weather-data powered applications can be found on nearly every smartphone and mobile device, which can in part explain the popularity of weather APIs (Wagner 2015).

In this project the API consumer is the Clear Skies mobile app. Through the use of APIs that are designed to query databases, the Clear Skies app can build upon existing available knowledge and information online, and use it as a foundation to develop the content of the app. As a result the developer is not burdened with a database that they must maintain on a yearly basis, although regular testing for accuracy and reliability of data will be a key concern. Efficiency is important to a project with a short implementation timescale and furthermore, APIs implementing the REST architectural style (RESTful APIs), often used in conjunction with the JSON data transfer mechanism, in particular are noted for their popularity, usability and simplicity (Hildebrand, C., Shankland, P. & Baya, Vinod 2011).

This project shows that it is possible to use these third party resources to encompass a broad range of celestial events. Such a design affords a scalable and maintainable product that can adapt to the preferences and requirements of the astronomy community. Given the fact that the developer is a newcomer to the field of astronomy, it is important to develop content for the app based on reliable, knowledgeable sources.

Ideally the Clear Skies application would eventually be able to cover a wide variety of celestial events – from meteor showers to planets to the aurora borealis to satellites and their iridium flares. It would provide a one-stop-shop for the user and eliminate the need to refer to different sources for specific celestial events.

2.10.3 Mobile

When considering a strategy to develop a mobile solution to the problem, it must first be noted that not all applications necessarily suit the mobile framework. There exists a whole breadth of research and understanding, not least the variation in mobile devices themselves (Kellingley n.d.) that must be addressed in order to satisfy the potential UI/ UX experience offered by mobile hardware.

Physically the I/O mechanisms differ, the screens are small and they have fewer pixels. Security is different in that mobile platforms are open and susceptible to malware that can affect other apps on a device and power consumption becomes a greater concern given that battery life of a mobile device is limited.

Psychologically the user is often in a very different state of mind when they approach a mobile app to when they approach a desktop one. Mobile implies *"on the move",* which suggests a sense of urgency that requires efficient execution of the app.

The market research detailed in Appendix F shows only one instance of a mobile app that informs the user of both the occurrence of a celestial event and optimal weather conditions for viewing it based on their location. This is a pay-for app. Of the other resources identified that do provide celestial event notifications, weather notifications are not included, and disappointment inevitably arises when the user subsequently checks the weather forecast for their location and finds on a regular basis that the night sky is cloudy. Arguably it becomes easier to explore the night sky using one of the many sophisticated, visualisation software offerings such as Stellarium, Celestia or GoogleSky. Opportunities to go outside and connect with science via the sky at night are missed.

Stephen Beasant, Secretary of the Northern Ireland Amateur Astronomy Society discussed at the January 2016 meeting how he did not value enhanced photographic images of celestial objects and events because as an experienced observer he had never seen them as such through his telescope. In his view, the experience of viewing a photograph from NASA's Hubble Space Telescope was not at all comparable to the satisfaction of discovering for oneself an object or event in the sky itself. A mobile software solution provides a simple way to support that.

Ultimately increasing cloud cover and light pollution will make observing the night sky more and more challenging, and lead to missed opportunities to exploit its wonder. In consideration of the effects of climate change it would appear that this resource is finite, hence all the more reason to do everything possible to ensure as many people experience it as possible.

Given the UK's pre-disposition to cloudy skies and the obstacle to night-time observing that they present, it follows that a mobile app that would alert interested parties to favourable viewing weather in their area would be a useful tool. Even more valuable would be an alert notification that gives individuals enough time if necessary, to travel to a location with a dark sky without compromising the accuracy of the weather prediction. A mobile app that would alert an observer in a timely fashion to favourable weather conditions for night-time viewing, would help to ensure that the effort taken to make the journey is worthwhile. By connecting people to celestial events, the app will offer tangible outcomes in the form of positive and memorable experiences.

Requirements Analysis

3.1 Functional Requirements

Users are defined as anyone with an interest in viewing celestial events in the night skies over the UK. The user stories are built upon the main findings of the Functional Requirements section of the Clear Skies questionnaire, as summarised in Appendix C. The user stories formed and continue to inform the product backlog (and in turn the release backlog and the sprint logs) as development continues within the agile process framework.

The epic agile user story (in bold) is broken down into smaller user stories. Two user stories are provided below. The full list of user stories can be found in Appendix G.

Epic User Story				
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.				
ID	Theme	As a	I want	So that
1	GPS	User	My geographical location to be taken into account	The accuracy of the notification is maximised
2	Alert Timings	User	Sufficient preparation time to travel to a dark area	I can view the celestial event in the darkest possible sky

3.2 Non-functional Requirements

Outlined below are the main non-functional requirements of the Clear Skies mobile application.

Efficiency is a priority due to the fact that Clear Skies is intended as a mobile application. Celestial events are typically viewable for a short period of time, unlike celestial objects, which may be viewable for months. Clear Skies is intended as a mobile application due to the portability constraint. In order to be useful to the user the application must be able to alert them to pertinent information at the

appropriate time. To widen the potential and future developments of the application as much as possible, it is API-focussed – benefiting from existing, maintained expert information in the form of API databases for celestial events and weather. Ideally, by focussing on a maintainable, scalable and modifiable resource, the project can develop comfortably in line with user requirements. In order for the Clear Skies app to be a valuable resource, it must be accurate and reliable. It must be testable to ensure this, and easy for the user to operate given the aim of the app is simply to facilitate an outdoor, real-world experience.

A table outlining the system constraints can be found in Appendix H.

3.3 Summary

This chapter has analysed information obtained from the research questionnaire in order to determine the end user requirements for the application. These requirements have been separated into functional and non-functional requirements in order to clarify the objectives of the project.

The Clear Skies project incorporates a hard deadline. By this time a functioning prototype was required to be built, tested and evaluated. A key aspect of the project management was to define a minimum viable prototype with prioritised extensions. Consequently not all of the desires expressed by the NIAAS focus group have been accommodated in this release but due to the incremental nature of the project's development, these features remain valid considerations for future development.

Design

4.1 Introduction

This chapter provides an overview of the graphical user interface as well as the system architecture and its key algorithms. User Stories, wireframes and UML diagrams were used in the development of each of these aspects of the application.

4.2 Minimum Viable Prototype

The prototype is intended to demonstrate that it is possible to create an application for mobile that combines location data with third party API resources to inform users of a celestial event if the weather conditions are favourable.

As a result the following aspects of design were prioritized:

- The application uses location data to inform the weather and astronomy-related queries that it makes
- The application evaluates the returned data and provides the user with an accurate result
- The application raises an alert notification that informs the user of a successful result
- The background service runs daily, even when the app itself is inactive
- The background service does not begin until the application has confirmed there is internet connectivity
- The application provides a simple, responsive user interface (UI)

The minimum viable prototype with prioritised extensions is defined in detail as per the Product Backlog in Appendix I.

The scope of app has been widened from Northern Ireland to UK-wide because the clear skies issue remains relevant. Broadening the scope geographically does not impact on the work required to gather and analyse data, and provides the added opportunity to demonstrate the contrast in results, which are dependent on geographic coordinates.

AuroraWatch and Open-Notify supply astronomy data to the minimum viable prototype. Both of these events are visible with the naked eye.

The functionality of the application relies heavily on the background work that it undertakes on a daily basis. By relying on the notifications raised by the app, it is intended that the user interface is not accessed regularly by the user. Despite this, it was necessary to consider in depth an appropriate user interface that was appealing and responsive to the user, as well as suitable for a mobile context.

4.3 Open Source

Using open source software packages allows work to be shared freely with others. The communities that exist to provide support to other users and developers are an excellent resource from which to learn and to be inspired. By using open source software in this development process I acknowledge the impact that amateur astronomy and its accessibility has had on the field of space science, as well as the wealth of understanding I have gained as a result of others who have contributed to this community. By sharing my work on GitHub I am to encourage others to alter, extend and contribute to my work so far.

4.4 Hardware

The Clear Skies application will be built for use with mobile devices because one of the main aims of the app is to help users make sure they do not miss out on a celestial event if they have the opportunity to view it in the night sky. As a result efficiency is an important aspect of the system design. The Central Processing Unit (CPU) power, memory and battery life typically offered by a mobile device are significantly less than that offered by larger devices such as laptops.

A number of factors indicate that the Clear Skies application is suitable for mobile:

- The information that is supplied is time sensitive.
- One of the main objectives of the application is that it informs a user of information that is interesting to the without them having to sit down with their laptop or desktop computer to find it.
- Part of the flavour of the app is that it facilitates spontaneity and excitement.
- Given the limited user interface the app is suitable for small screens.

- Given its limited interaction with the user it is also suitable to be handled on the go.

In terms of an app resource-consumption model, the target users would not expect the app to shorten their battery life significantly given that it is likely that other features of their device such as telephone and email take priority. As a result it is important to work with their expectations and provide an app that does not impact negatively on battery life.

4.5 Native or Hybrid Mobile Development

Broadly, when compared to web apps, native apps are considered to have better performance, access to a broader range of platform specific features and better looking and more responsive UI (Lionbridge 2012). Downsides however are the lack of ease with which the developer can scale the application across new platforms and with each new set of code comes the requirement to maintain it. Wasserman [8] asserts that mobile development tools greatly simplify the task of implementing a mobile application. Arguably hybrid application platforms take that one step further, allowing for the creation and maintenance of cross-platform mobile applications in a quick, relatively straightforward and efficient way. They remove the overhead associated with programming and maintaining native apps on multiple platforms using multiple languages and multiple developing environments. All of these benefits support key requirements of business effectiveness and efficiency by getting apps to a wide market in the shortest possible time.

Despite these advantages and with timescales in mind, the developer's existing knowledge of Android Studio and Java (and access to the extensive documentation that comes with them) has led to the decision to build an Android application. Android Studio offers a complete IDE. It integrates an editor, debugger, emulator and application builder into one tool. Its also free of charge (Prusty 2015). It benefits from extensive testing and debugging features including on-device testing. This is useful in sidestepping some of the difficulties with testing for example on an iOS device, which normally requires cryptographic signing before copying it to the hardware.

In order to deploy and application to a wide range of channels, the app must be suitably developed to complement the wide variety of mobile devices and operating system releases. Testing is extensive and critical, and becomes more complex in a hybrid context. Developing a hybrid application is to be considered for future development.

4.5 Graphical User Interface Design

It has long been the case that the conceptual metaphors in many UI designs centred and still centre on constructs derived from workplace environments (Moggridge 2006). The very nature of mobile hardware and its rapid integration into our daily lives has helped to change our approach to user interface design. Donald A. Norman advocates usability as a primary concern for designers. His support for a user-centred approach emerged out of a frustration with bad design (Norman, 2004, p. 78). His "crusade against unusable objects" (Norman, 2004. p.4) has impacted deeply upon the overall field of design, remaining influential in the area of HCI, which is a key component of the success of the Clear Skies application.

Perusal of existing astronomy apps makes clear that they are often laden with information. The aim of the Clear Skies application is to assist the user in finding and potentially learning more about events and/ or objects in the night sky. Given the variety of information and interactive graphics on offer, personal experience of these apps has demonstrated how easy it is to become overly engaged in the app itself and less focused on the business of night viewing. Indeed the extent of information can easily become overwhelming and discouraging.

Perhaps the most compelling case for straightforward, accessible and usable design is the advantage of inclusion. The W3C organisation outlines the similar barriers experienced by "Users of mobile devices and people with disabilities… when interacting with web content". By accessing W3 web accessibility tutorials as well as adhering to the developer design guidelines laid out by Android, the app has the potential to serve well a wider audience, including people with disabilities, older people, those whose first language is not English and infrequent users.

Good software design for mobile exists. The Clear Skies application aims to take advantage of this by emulating a style of interface that is both familiar and appealing. It takes as a departure point a typical weather forecast user interface. The UI displays a number of pieces of information in a ListView, the information itself being organized by priority, with the most pertinent information to the user displayed with prominence at the top of the user's screen.

The current UI has not deviated significantly from its original form. Figure 5 depicts the user interface conceived at the outset of the project. The interaction is simple, clear and requires minimal user input. Pertinent information is displayed dynamically:

- CITY displays the nearest city, town or village
- EVENT displays the celestial event
- WEATHER displays the weather forecast

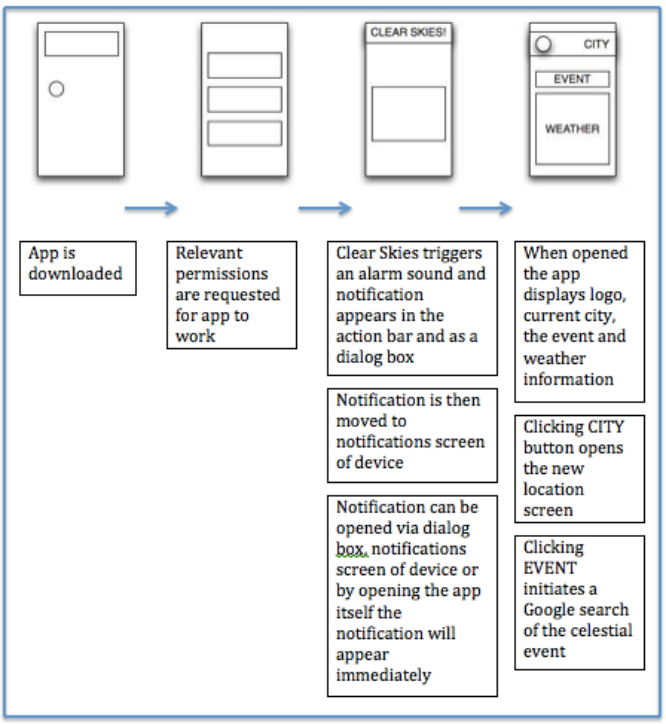


***Figure 5**: Early Clear Skies User interface design (Alert Notification)*

The actors are amateur astronomers from beginner through to intermediate and advanced observers, and the foundation of their individual interactions with the app are the same, regardless of the level of their expertise.

Key to further development has been the inclusion of a Settings Activity. The user is encouraged to tailor notifications to best suit their individual requirements and once finalised, their interaction with the app outside of receiving notifications is minimal. Users decide on celestial events that are of interest to them as well as their preferred daily time to query visible celestial events.

Approaching the UI as a 3D object, the design takes into consideration location based services (LBS). By offering the functionality to query events based on the user's roaming location, the app becomes a intuitive and responsive addition to the user's environment. Currently this is the only location option offered by the application, but the intention is to offer users the opportunity to input their own fixed location in future development of the application.

User cases for the Clear Skies app are provided in Appendix J.

Currently the prototype app is fixed in portrait mode. The UI is best viewed in this mode, and it is the predominant way that individuals use their mobile device.

4.4.1 The Main User Interface

Wasserman asserts:

> "With the challenge of making the best possible use of limited screen space, user interface design takes on greater importance than ever".
>
> (Wasserman 2010)

He further highlights the context in which mobile devices are often used – often on the move when there is time to complete a quick task – and the importance of providing a screen that highlights the most frequently used features.

Bearing this in mind, and in keeping with Shneiderman's Golden Rules of Interface Design (1986), the app is designed to respond to user interaction in a useful and efficient way. The user will receive helpful feedback from the app. When their

location is outside of the UK, an informative and friendly message alerts the user to that. The same logic applies if no network connection is available or if the background work does not return a successful result.

The UI supports in their decision-making by offering some default selections in the event that they are not yet ready to make their own.

In order to view all pertinent information relative to a notification, the user needs only to touch the notification to open the main UI to view it, essentially providing a shortcut not just for frequent users, but also rather for all users.

A Refresh button is not recommended by Android (Udacity, Developing Android Apps, n.d.) but it has been included in the design in order to give the user more control over the service.

Given the resource constraints of the mobile platform, it is important to consider an efficient layout. Inflating complex layouts can be expensive, and can affect the application's performance and responsiveness. A List View is an economical decision in this instance because it recycles views, only inflating them as the user scrolls down the screen.

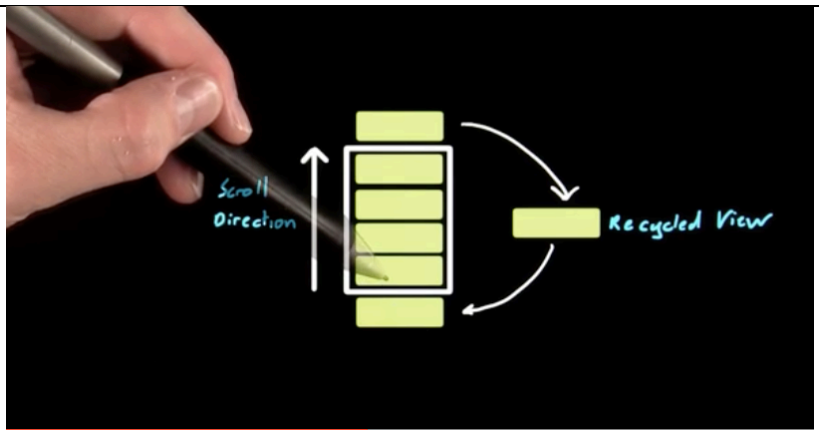


Figure 6: *List View functionality visualisation (Udacity, Developing Android Apps, n.d)*

The amount of information displayed to the user will depend on the result of the background service, so it is important to have a layout that can respond dynamically to this.

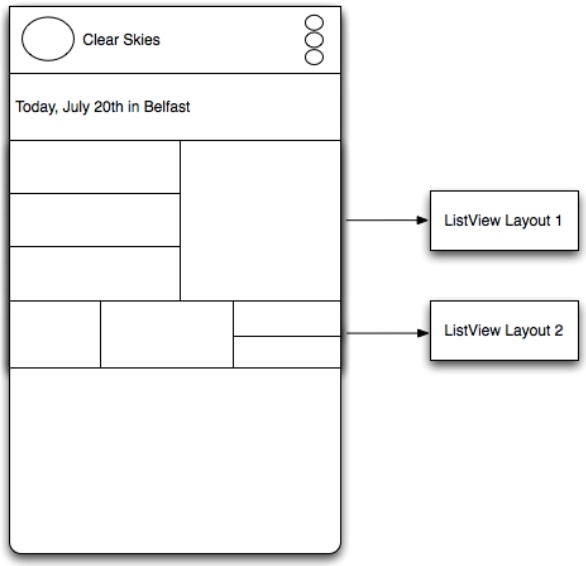


Figure 7: *Main UI Wireframes with ListView Layouts*

The main user interface is built on simple wireframes. The root layout is a Frame Layout which ideal for simple layout designs that do not change significantly during the application lifecycle. Two relative layouts are used to distinguish between the application overlay, which is a simple Image View required for first time use of the app, and the main UI which the user is presented with subsequent to first use. According to the Android Design Principles the first thirty seconds of interaction with an app should be short, frictionless, professional and speak to the user.

The main UI Relative Layout is divided into a simple Text View that shows the date in a friendly format, and a List View, which displays other information to the user. Depending on the information to be displayed, the format of each List Item in the ListView is defined and implemented accordingly by way of an Android Array Adapter (as visualised in Figure 8).

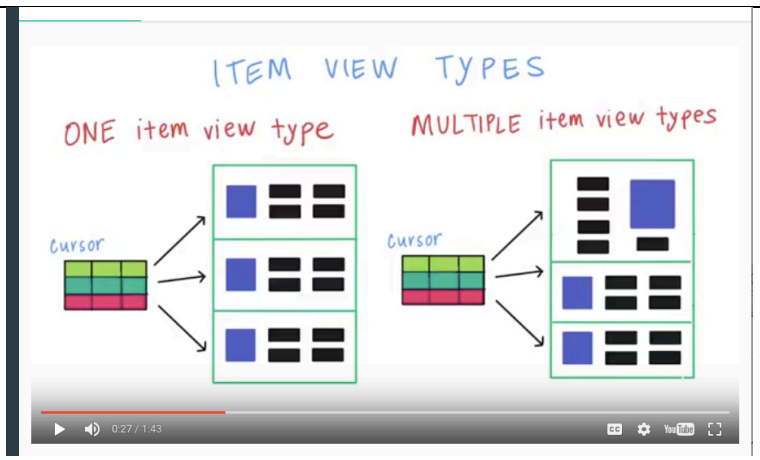


Figure 8: *Defining List Views (Udacity, Developing Android Apps, n.d)*

Screenshots of each implementation are detailed in Figure 9. Clearly visible is the date, the overlay, and the different List Views.

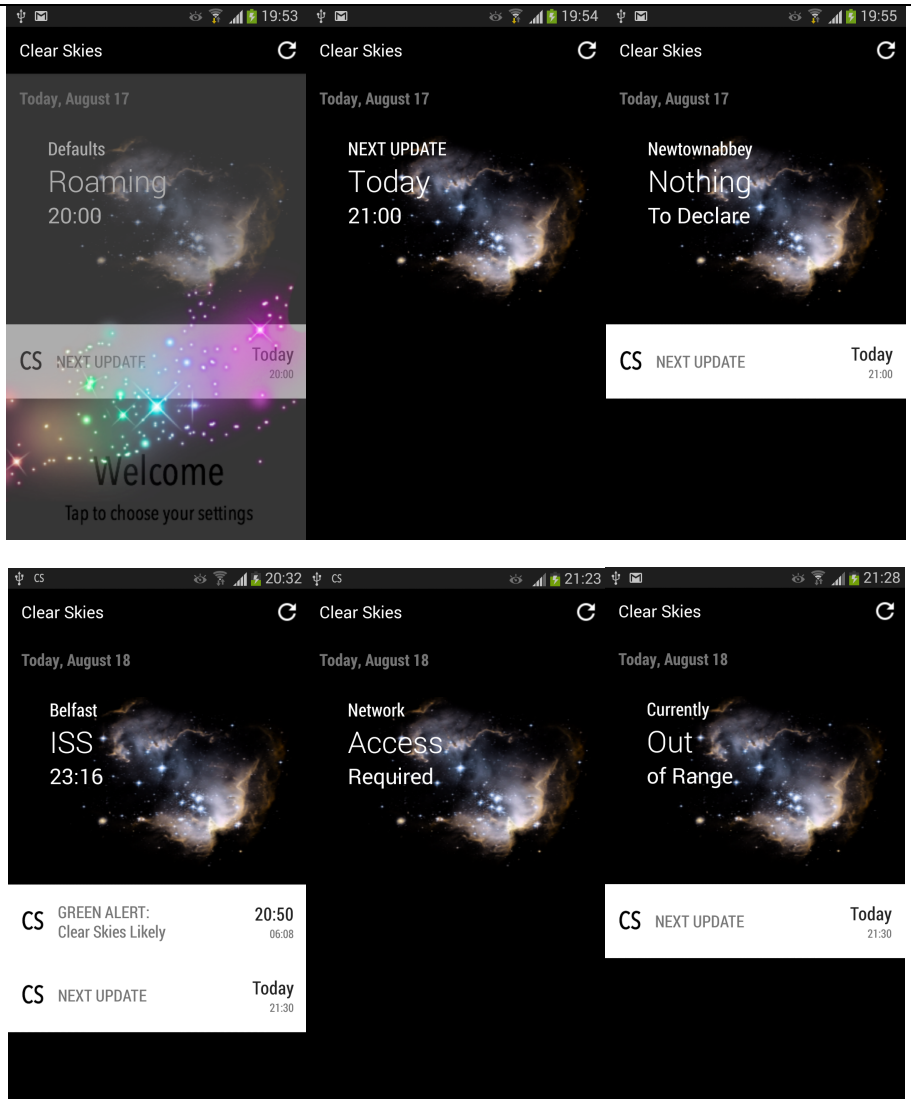


Figure 9: *Clear Skies Main UI Screenshots*

The black List View items that are designed with a background image and white text display the most pertinent information to the user. The aim of this approach is to assist the user who does not have much time to check the service. Other less pertinent information is also clearly displayed in the white ListView items below it.

An important part of the UI is that it updates dynamically. It confirms to the user their settings and by using the friendly date format and programming the interface to display Today or Tomorrow text accurately, the user gets a sense that the application is working and responsive. This is particularly important given that this application will not regularly display an event notification.

4.4.2 The Settings User Interface

The Settings UI is an extension of the Android Preference Activity class. It affords the Settings Activity the uniform feel of any Android application settings. This sense of familiarity reflects positively on the user, and helps to give the application is native platform feel. From a developer's perspective, check boxes and radio buttons are already designed, so UI design is assisted in this regard.

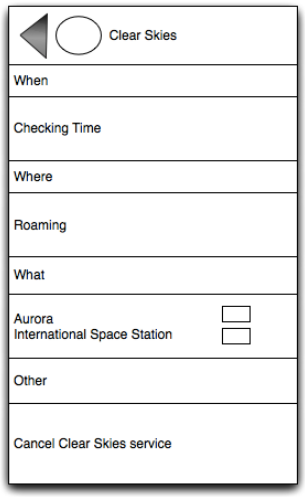


Figure 10: *Settings UI Wireframes*

Android offers a Time Picker widget that has been implemented in the Settings Activity to allow the user to select the time at which they want the daily checks to occur. Once the preferred time is selected, it is updated in the summary of the Checking Time section, so it is clear and confirmed the user the time that has been set. A toast notification also confirms this, as a way of providing positive feedback to the user.

A cancel button has been designed but not yet implemented. The aim of this button is to allow the user to explicitly turn off the service. Given that the app uses background services that are triggered even when the app is not active, it is important that users can disable the app and receive feedback confirming the case.

AuroraWatch make available on GitHub source code for a basic Android application that is not advertised on their website[8]. Through trying this application out it became clear that the polling service that it used greatly affected the battery life of the mobile device. It was frustrating to find the device quickly running out of battery on a regular basis and the only sure way to make sure the background service was cancelled was to uninstall the app. The Cancel button is intended to allow the user to have more control over the application. Also worth considering in terms of future development is the app's ability to respond to Android State Change broadcasts that and how to inform a user if Android has killed the app.

Checkboxes are used to select event preferences because the Android Multi Select List Prefs option only works from API 11.

[8] https://github.com/stevemarple/AuroraWatchApp

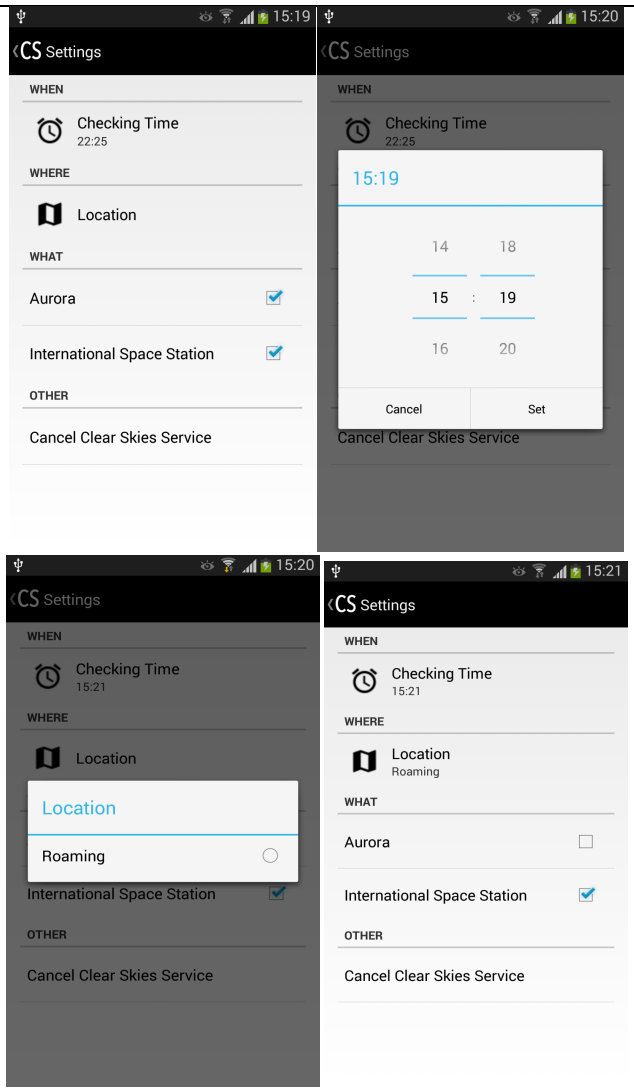


Figure 11: *Clear Skies Settings UI Screenshots*

4.4.3 The Alert Notification

Notifications, as an important part of the Android user interface, have their own design guidelines. To date a simple notification has been implemented with a view to considering the implementation of a richer UI as part of future development of the application and its potential for wearables. The Alert notification very simply shows the pertinent information relating the alert – namely the event itself and that Clear

Skies are forecast. The notification is built using the Notification Builder provided by Android. The notification appears with the app logo in the device notifications.

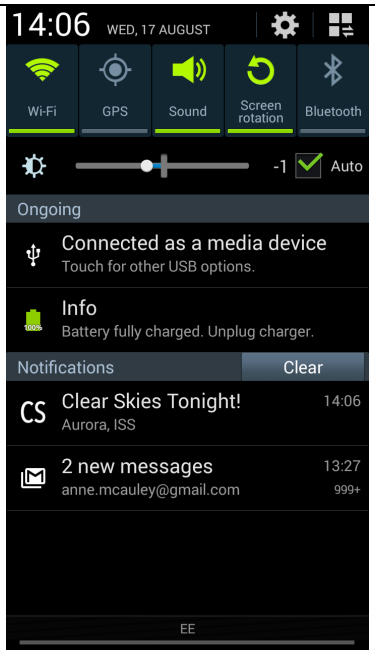


Figure 12: *Clear Skies Notification Screenshot*

When clicked, the notification takes the user to the Main Activity of the Clear Skies app. The Main Activity displays the most recent result that caused the alert to be raised.

4.4.4 Colour Scheme, Imagery and Font

The layout and formatting of the app is guided by the Android documentation on design. Fonts have been referenced from a Google made app tutorial *(Udacity, Developing Android Apps, n.d).*

The imagery used was found via a Google Search. Both of the images were referenced in the Google Search as cost-free and free-to-use. Before wider dissemination of the application, the next step would be to contact the image owners and confirm this is the case.

A black background with white text has been selected for a number of reasons:

- It is less eyestrain to read white text on a black background when you are in a low light environment.
- White text on a black background uses less battery.

(Rebecca 2012)

Furthermore, improving colour contrast for accessibility also improves the mobile experience for all users (McNally 2013).

The minimum height of each List Item is fixed to the Android default that ensures they are never too small to tap with a finger.

4.4.5 List View Information

The layout is designed in such a way that it would be easy to amend the UI and change or increase the information provided to the user if necessary. This is particularly important given that the important information relating to each celestial event will vary.

Future development intends that by pressing a given List Item the user would be provided with more detailed information. This means that it is available if required but does not clutter the UI or overwhelm the user if not.

4.5 Architecture

A summary of the system design is outlined in Figure 13 overleaf. The fundamental elements of the system design are the Wi-Fi connectivity, the access to LBS and the astronomy and weather APIs, which provide the main content required for the app. The queries are informed by a number of factors including location at the time of the background check. The need for efficiency drives the design of the API queries that are necessary to deliver the app content. Queries are only initiated when specific conditions are met as indicated in Figure 8.

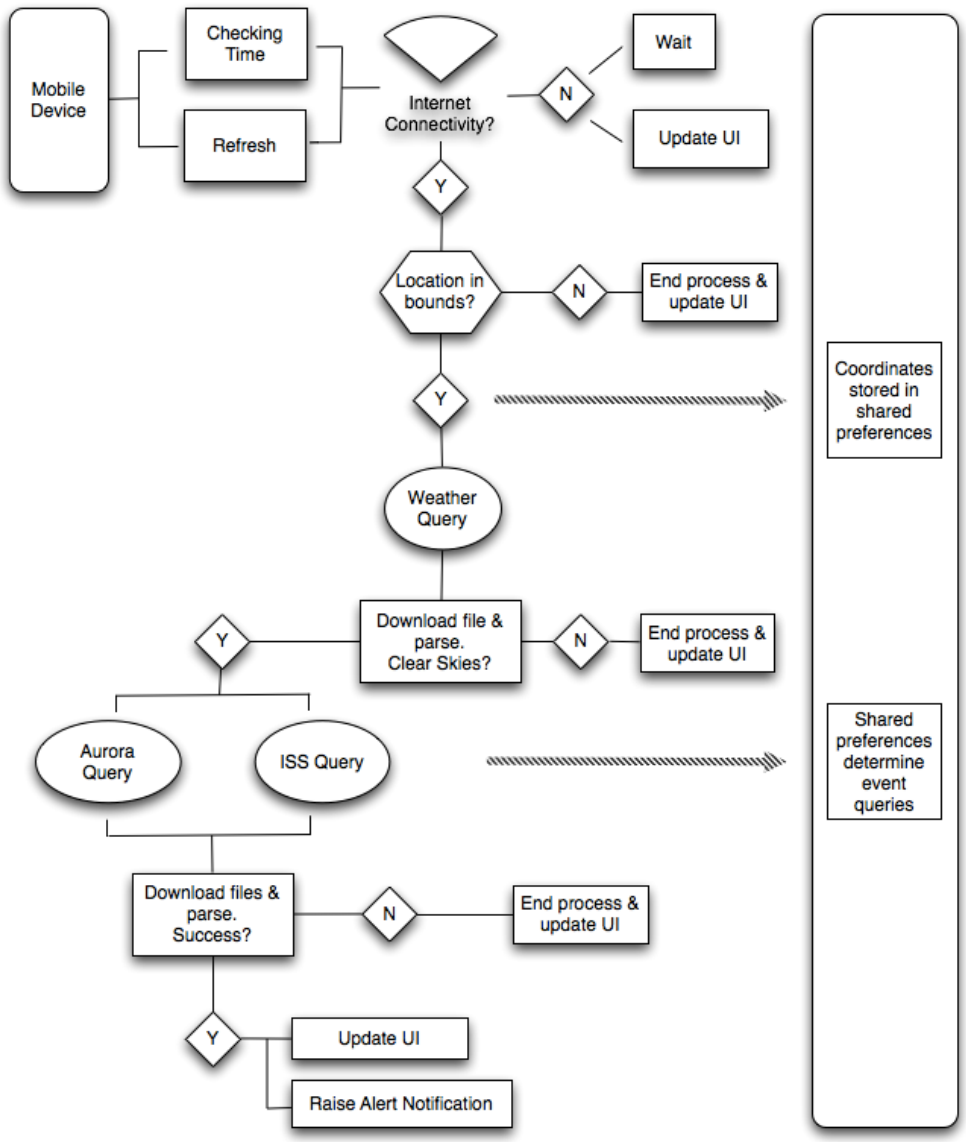


Figure 13: *Clear Skies Architecture Design Visualisation*

4.5.1 Location

The app's location preference currently allows only for "roaming" (determined by accessing user's current coordinates when the background work begins). The coordinates are validated before network calls are made. The option for the user to input their location in text or coordinate form, although an important and valuable extension, is deemed to be beyond the scope of the minimum viable prototype due

to the fact that the current preference options provide for context-based results and demonstrate the app's adaptability.

4.5.2 Checking Time

The user is required to input a time that best suits them for the visible event query to be made. The reason for this approach is based on a number of factors. The AuroraWatch API (and the SkyWatch API) is updated in real-time. In order to ensure that a user does not miss out on an event that they could have viewed, they are asked to provide the latest time at which they would like the query to be made. Users are advised to factor in the distance they usually travel (if any) to access dark skies. They are also able to consider their personal schedule when making the decision. For example, it is unlikely on a weeknight that a user would benefit from results after 10pm at night if they have to travel 50 miles to a dark site and they start work at 9am the next morning. The aim here is to minimise the negative impact to the user of missing an event that is not visible over the period of a few days, as is often the case with the aurora. The AuroraWatch creators also point out that if they measure an increase in geomagnetic activity during the day, it is likely that this will follow into the evening. They cite this justification as one of the mitigating factors of receiving alerts in daylight.

The Clear Skies notifications that are raised will always be bound by sunset and sunrise when events in the night sky are best viewed. Future planning will consider the use of Firebase Cloud Messaging (FCM). It offers the opportunity to listen for and trigger notifications to devices based on real-time updates to database resources.

The decision to focus on FCM in the future is based on their status as a (currently) free service that is Android compatible and is the successor to Google Cloud Messaging (GCM) which has been recommended in a number of Android development textbooks as a more efficient alernative to polling (Darcey & Conder 2012, p. 400). In principle this approach would allow a user to define a time period than a specific time, and further reduce the chance of missing out on an event.

4.6 Location Services

The device coordinates are checked to confirm they are with in the latitudinal and longitudinal bounds of the UK. The bounds have been determined using the map provided in Appendix K.

```
        sendBroadcast(i);
    }

    // Check that the coordinates are within bounds
    public static boolean withinBounds(double lat, double lng) {

        boolean withinBounds = false;

        if ((lat >= 50.0 && lat <= 60.0) &&
                (lng >= -9.0 && lng <= 2.0)) {
            withinBounds = true;
        }
        return withinBounds;
    }
    // Validates resource references inside Android XML files
    public GPSService() { super(GPSService.class.getName()); }

    public GPSService(String name) { super(name); }

}
```

***Figure 14**: Clear Skies Algorithm: Coordinates within UK*

4.7 API Queries

The API resources selected for the minimum viable prototype are RESTful services. REST is a way of interacting with resources on the web using a simple URL (Pstatz, 2010).

4.7.1 Astronomy

From the analysis undertaken, the API resources considered suitable for the Clear Skies prototype are listed below:

- AuroraWatch: http://aurorawatch.lancs.ac.uk/api_info/

Provides real-time alerts of when the aurora is likely to be seen from the UK

- Open-Notify: http://open-notify.org/

Provides overhead pass predictions for the International Space Station

AuroraWatch UK has been selected to provide information on the aurora because the APIs are simple, reliable and free to use. Both resources return only a small amount of data. They demonstrate real-time and predicted data handling as well as the handling of data in both JSON and XML formats. Critically, both of the astronomy APIs provide meaningful analysis of raw data that can be applied directly to the Clear Skies app with minimal processing. Another ISS API *Where The ISS At*[9] was considered for use. It provides the location of the ISS at a given time, but the developer must determine its visibility in relation to the relevant land coordinates.

The SkyWatch and N2YO APIs will form part of the next phase of development. When contacting each of them they were very helpful. In particular upon request from the developer, SkyWatch were able to provide a Java example of how to use their API.

4.7.2 Weather

Forecast.io has been selected to provide weather data to the app due to its favourable usage terms and the fact that it is used by *Clear Outside*[10] to power their astronomy focussed weather app. *Clear Outside* was recommended by a participant in the NIAAS survey. The website and app are offered by First Light Optics, who state on their website that they are the UK's largest Astronomy retailer. A similar North American based astronomy weather forecast called the Clear Sky Chart was also consulted[11]. The parameters of the weather query are based on a traffic light system they offer astronomers who are keen to find out quickly the likelihood of Clear Skies for observing according to their location. After contacting Clear Outside, they indicated that it was not possible to share the criteria that they used to determine their traffic light system, but that by looking at the data closely that it would be straightforward to determine the parameters that they use.

---

[9] http://wheretheiss.at/

[10] http://clearoutside.com/forecast/50.7/-3.52/

[11] http://www.cleardarksky.com/csk/

By looking at different locations at different times, it was possible to make assertions about the criteria. The results are detailed in Appendix L.

The Forecast.io query is built with the developer's unique API key and the device coordinates:
https://api.forecast.io/forecast/57e606614d55dbee13c97a1736097f91/54.6411845,-5.9382939

The result is displayed in Figure 15.

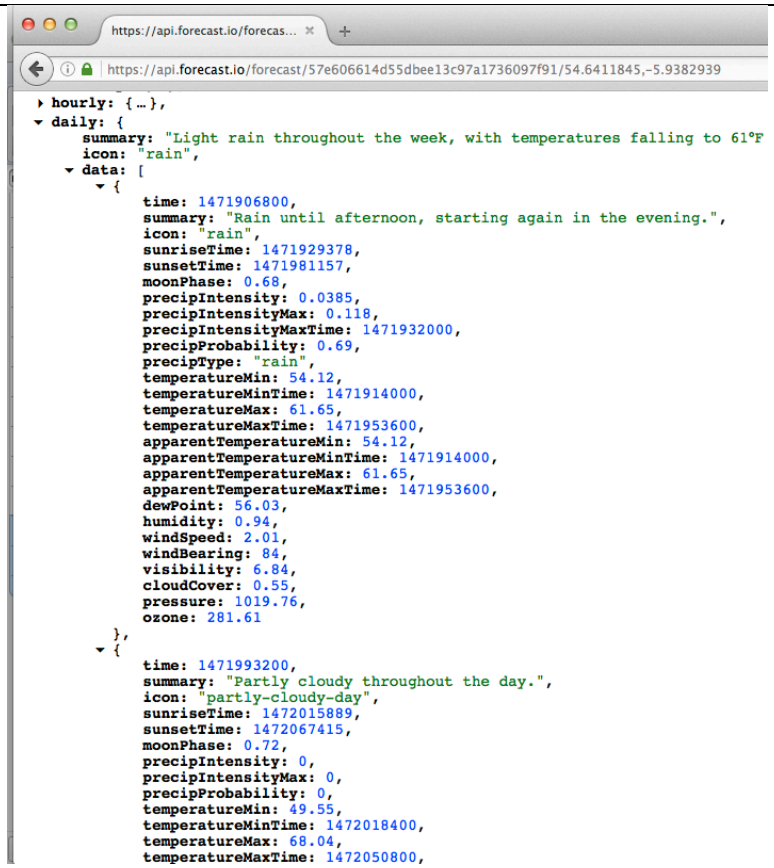


Figure 15: *Forecast.io API Call (JSON)*

The code that is implemented to determine the likelihood of Clear Skies:

```
JSONObject yesterdayForecast = dailyForecast.getJSONObject(0);
long sunsetTonight = yesterdayForecast.getLong("sunsetTime");

// DETERMINE CLEAR SKIES

if (cloudCoverPercent <= 0.3 && precipProb <= 0.25
        && humidityProb <= 0.8 && visibilityMiles >= 9) {
    weatherSuccess = true;
    weatherTier = 0;

} else if (cloudCoverPercent <= 0.5 && precipProb <= 0.5
        && humidityProb <= 0.9 && visibilityMiles >= 6) {
    weatherSuccess = true;
    weatherTier = 1;

} else {
    // JUST FOR NOW FOR TESTING KEEP WEATHER SUCCESS AS TRUE
    //weatherSuccess = true;
    //weatherTier = 0;
    weatherSuccess = false;
    weatherTier = 2;
}

// SAVE THE INFO NEEDED IN OTHER PARTS OF THE APP IN THE SHARED PREFS
// SAVE SHARED PREFS BASED ON WHETHER OR NOT WEATHER IS A SUCCESS
// IF NOT SUCCESSFUL, ONLY REQUIRE SUNSET & SUNRISE TIMES
sharedPrefs = PreferenceManager.getDefaultSharedPreferences(context);
```

***Figure 16**: Clear Skies Algorithm: Weather Traffic Light System*

It is important to note that ideally this algorithm would also take into account the phases of the moon as this impacts directly on how dark it is. This inclusion is planned for a future iteration of the application. Before a release, further cross-referencing and testing of the weather parameters would be initiated, including further research into the impact of the pressure parameter, which is not clearly evidenced from the Clear Outside weather forecast analysis, but does impact on the prevalence of Clear Skies.

4.7.2 Aurora

The AuroraWatch query URL is generic, with no specific parameters.

AuroraWatch query: http://aurorawatch.lancs.ac.uk/api/0.1/status.xml

AuroraWatch requests that a header is added to the API call in order to identify the user to the service providers. It has not yet been implemented in the application.

The result is displayed in Figure 17.

http://aurora...1/status.xml http://api.open-notify.or...

aurorawatch.lancs.ac.uk/api/0.1/status.xml

This XML file does not appear to have any style information associated with it. The docum


```
– <aurorawatch>
  – <current>
      <state name="red" value="200" color="#ff0000">Red alert: aurora likely</state>
    </current>
  – <previous>
      <state name="green" value="0" color="#33ff33">No significant activity</state>
    </previous>
    <station>SAMNET/LAN2. Lancaster, UK.</station>
    <updated>2016-08-23 13:37:02</updated>
  </aurorawatch>
```


Figure 17: *AuroraWatch API Call (XML)*

The code that is implemented to determine the likelihood of a visible Aurora:

```
sam
            // check whether a possible siting is likely
            if (auroraForecast.equals("No significant activity")) {
                Log.e(LOG_TAG, "Nothing to show: " + auroraForecast);
                auroraSuccess = false;
                // Update sharedPrefs for testing
                // sharedPrefs.edit().putString("auroraForecast", auroraForecast).apply();
                // auroraSuccess = true;

            } else if (auroraForecast.equals("Minor geomagnetic activity")) {
                // Aurora may be visible by eye from Scotland
                Log.e(LOG_TAG, "Aurora may be visible by eye from Scotland: " + auroraForecast);
                // Put in test of geo coordinates here
                if ((lat >= 55.0 && lat <= 60.0) &&
                        (lng >= -8.0 && lng <= -2.0)) {
                    auroraSuccess = true;
                    // Update sharedPrefs
                    sharedPrefs.edit().putString("auroraForecast", auroraForecast).apply();
                }
            } else if (auroraForecast.equals("Amber alert: possible aurora")) {
                Log.e(LOG_TAG, "Aurora is likely to be visible " +
                        "by eye from S, NE, NI: " + auroraForecast);
                // Put in test of geo coordinates here
                if ((lat >= 54.0 && lat <= 60.0) &&
                        (lng >= -9.0 && lng <= 0.0)) {
                    auroraSuccess = true;
                    // Update sharedPrefs
                    sharedPrefs.edit().putString("auroraForecast", auroraForecast).apply();

                } else if (auroraForecast.equals("Red alert: aurora likely")) {
                    Log.e(LOG_TAG, "Aurora is likely to be visible " +
                            "from anywhere in the UK: " + auroraForecast);
sam (androi
                    // Flag aurora success
                    auroraSuccess = true;
                    // updateSharedPrefs
```

Figure 18: *Clear Skies Algorithm: Likelihood of a Visible Aurora*

Again the latitudinal and longitudinal coordinates are checked because the traffic light system that is used by AuroraWatch relies on the user to take into account their location when viewing a notification.

- Minor Geomagnetic Activity – Aurora may be visible by eye from Scotland
- Amber Alert: Possible Aurora – Aurora may be visible by eye from Scotland, North of England and Northern Ireland
- Red alert: Aurora likely – Aurora may be visible from anywhere in the UK

4.7.3 ISS

The Open Notify query does not require an API key but does require the device coordinates in order to produce a result:

http://api.open-notify.org/iss-pass.json?lat=54.6411845&lon=-5.9382939

The result is displayed in Figure 19.


```
{
    message: "success",
  ▾ request: {
        altitude: 100,
        datetime: 1471967189,
        latitude: 54.6411845,
        longitude: -5.9382939,
        passes: 5
    },
  ▾ response: [
      ▾ {
            duration: 488,
            risetime: 1471971636
        },
      ▾ {
            duration: 471,
            risetime: 1472031864
        },
      ▾ {
            duration: 608,
            risetime: 1472037531
        },
      ▾ {
            duration: 633,
            risetime: 1472043281
        },
      ▾ {
            duration: 623,
            risetime: 1472049054
        }
    ]
}
```


Figure 19: *Open Notify API Call (JSON)*

The result returns the upcoming passes (usually five). Currently the algorithm that determines a successful result considers only passes due for the day of the query, and then checks that they take place an hour after sunset. The hour given is intended to take into account twilight – as it does not get dark immediately at sunset. It is worth noting that many factors affect how long twilight lasts, including location and time of year.

```
Date sunsetDate = new Date(sunset * 1000L);
long today = System.currentTimeMillis();
Date todayDate = new Date(today);
DateFormat df = new SimpleDateFormat("d MMM");
String sunsetDf = df.format(sunsetDate);
String todayDf = df.format(todayDate);
Log.e(LOG_TAG, "sunset (long) " + sunset + " and today (long) " + today);
Log.e(LOG_TAG, "sunset date " + sunsetDf + " and today date " + todayDf);

// unix timestamp * 1000L to "upcast" to Long and multiply by 1000 since since
// Java is expecting millisecs
//taking twilight (1hr) into account but varies according to coords
Date darkD = new Date((sunset*1000L) + (60*60*1000));
DateFormat dfDark = new SimpleDateFormat("HH mm");
String darkDf = dfDark.format(darkD);
Log.e(LOG_TAG, "dark date " + darkDf);

// It is possible for the ISS to passover more than once in the same night
for (int i = 0; i < passes.size(); i++) {
    long risetime = passes.get(i).getLong("risetime");
    Date risetimeDate = new Date(risetime * 1000L);
    Log.e(LOG_TAG, "risetime " + risetime);
    Log.e(LOG_TAG, "risetimeDate: " + risetimeDate);
    String risetimeDf = df.format(risetimeDate);
    Log.e(LOG_TAG, "risetimeDf: " + risetimeDf);
    if (risetimeDf.equals(todayDf) && (passes.get(i).getLong("risetime") > sunset)) {

        Log.e(LOG_TAG, "pass df: " + sunsetDf + " today df: " + todayDf);
        Log.e(LOG_TAG, "sunset: " + sunset + " risetime: " + risetime);
        passRiseTime.add(passes.get(i).getLong("risetime"));
        // Flag that there is a result
        issSuccess = true;
        // Update the sharedPrefs that will populate the UI
        sharedPrefs.edit().putString("onForecast", passRiseTime.get(0).toString()).apply();
    } else {
        issSuccess = false;
        // just for testing
        //issSuccess = true;
        // passRiseTime.add(passes.get(0).getLong("risetime"));
        // sharedPrefs.edit().putString("onForecast", passRiseTime.get(0).toString()).apply();
        //sharedPrefs.edit().putString("onForecast", "1471558560").apply();
    }
}
```

Figure 20: *Clear Skies Algorithm: ISS Night Pass Over*

The ISS API is queried daily if necessary because the data provided is a forecast. Due to the fact that the ISS is normally only visible for a short period of time it is important that the time provided is accurate. Therefore it is deemed worthwhile to instigate a new query daily, thereby accessing the most up to date information.

Implementation

5.1 Introduction

This chapter details the implementation of the Clear Skies application. The chapter documents the implementation process, looking at how design decisions were realised and the justification for decisions made along the way. Development of the application has taken place in agile sprints. Appendix I details each sprint and the release schedule gives an overall view of project timescales. The UML diagrams supporting the software system structure are presented in Appendix M.

5.2 System Overview

5.2.1 Minimum and Target SDK

The Minimum SDK is API 10: Android 2.3.3 (Gingerbread). API 10 is the cut-off for Google Play Services and currently incorporates 99.7% of Android devices. To date the cost of supporting new users in lower version has not been significant. Devices used in testing support the minimum feature set but this needs to be fully tested. The Android appcompat support library provides backward compatibility.

Device usage follows a bell curve; the highest number of devices is typically two years behind the current. Currently API 21-22: Lollipop 5.0 – 5.1.1 is the most popular device. The target SDK for this project is API 18: Android 4.3 (Jelly Bean). The target SDK defines the specification of the device that the application was developed on. Android recommend the target SDK should be the most recent but given project budget constraints this was not possible.

5.2.2 Structure

Fundamental to the design of the Clear Skies app is the requirement of Internet access before the background services proceed. When the alarm is triggered it checks the system connectivity and if no Wi-Fi or metered data is available it waits until the system state changes and while waiting it updates the UI with “No Network Access” if necessary. Background tasks are triggered once daily by the Alarm Manager in the form of a Pending Intent. The background tasks are defined within an Intent Service class, whose work is carried out off the main UI thread. Given that

the background work requires network services, this ensures that the responsiveness of the main UI does not degrade (Darcey & Conder 2012, p. 204). Furthermore it ensures that the background work is initiated regardless of whether the app is currently active. The background work that takes place and the alarm that initiates it are dependent upon the user's Shared Preferences. The relevant weather and astronomy information is downloaded via a stream connection and parsed in order to examine its contents. The UI is updated via an Array Adapter and notifications are raised using the Notification Manager class as appropriate.

5.3 Mobile IDE and Platform Specialization

Mobile is a key non-functional requirement of the system software. Given the project priorities, time constraints and the developer's existing knowledge of and experience with Java, the app has been developed for Android. Android Studio was selected over IntelliJ because it is free to use, recommended by Android and offers helpful UI design assistance.

The Android Studio IDE provides the tools required to build the Clear Skies application. It can be used to program access to device Wi-Fi and location data and wake up the CPU. It provides integrated access to Git and supports the Model View Controller (MVC) design pattern. By supporting the MVC pattern, the flexibility to refactor means the application can evolve and scale up as required. Future plans to increase the data resources provided by the application, to connect it to the cloud and take advantage of the push notifications offered by FCM are unhindered.

Building and deploying the app has been very straightforward and the build tool allows for unlimited private projects. A click built the app and a link sent by email allowed for immediate distribution of the app. The Clear Skies application has not been submitted to the Google Play Store for approval.

5.4 Location

This functionality was initially developed with the Android Location Manager class. Although it provided a successful result, the code was changed to incorporate the most up to date method, namely the Google Location Services API, which is part of

the Google Play Services. Google Play Services is a bundle of services and APIs from Google that can be used for lots of features in Android apps (Jakuben 2014).

This upgrade has backward compatible support and works as far back as the Gingerbread OS. Due to the fact that

- The application requires Wi-Fi
- The precise coordinates are not essential
- It is important that the background tasks are completed regardless of whether the user is outdoors or indoors

the implementation focussed primarily on assisted GPS. Assisted GPS uses the nearby Wi-Fi hot spots and cell towers to triangulate a user's location (Nazmul 2010).

Android provides the Fused Location Provider API, which used in conjunction with a Google API Client, simplifies the process of obtaining location information via the best means. Balancing the requirements of the application with the power constraints of the mobile platform, the decision was made to select *PRIORITY_LOW_POWER*, which provides *"city"* level accuracy. A request to return only one successful location result is specified to avoid opening and closing location listeners unnecessarily and the app can access location data from other applications if they are accessing it more regularly.

5.4.1 Latitude and Longitude Within Bounds

The retrieved device coordinates are checked by the application before the remaining background services are initiated to ensure that the query will relate to a location within the UK. The Android Geofencing API was considered as an option for this check but ruled out because its function appears to focus on small areas and requires fine location detail in order to work properly.

Although Clear Skies has requested *ACCESS_FINE_LOCATION* in the manifest in order to ensure the device coordinates are accessed regardless of the surrounding environment, it does not require such level of granularity in order to carry out its function. Determining coordinates by Wi-Fi gives sufficient accuracy and greatly

improves the responsiveness of the background services given that an individual is likely to be indoors at night when the service is initiated.

The device coordinates are converted into a text format for display on the UI to give the user a sense that the UI is responsive. The Google Maps Geocoding API is used to achieve this.

5.5 APIs

5.5.1 Network Connections

The HttpURLConnection class was used to stream data. Android has declared it to be both lightweight and optimised for their platform; it is recommended over the HttpClient interface, which they state can be patchy.

Currently the background work always results in one network connection opening to access the weather API. If weather conditions for night viewing are favourable, two further connections are opened to access the Aurora and ISS APIs if they are selected in the user preferences. In terms of future planning, if this application were to continue adding data resources in this way, it would be important to consider the impact of opening a new connection each time. Although in theory it makes sense to only access and download data if its required, prefetching the data can actually be more efficient in certain circumstances ((Udacity, Developing Android Apps, n.d), n.d.). The Dalvik Debug Monitor Server (DDMS) provided by Android Studio can be used to measure network connectivity required to run the application.

5.5.3 Downloading Files

When a RESTful API is accessed, the content of its data is downloaded to a file locally on the device. Once downloaded a Broadcast is sent out to be received by one of the inner class BroadcastReceivers and once received, the file is then accessed and parsed.

Other solutions were considered that would allow the data to be accessed and parsed, without the need to download it to a file locally. One of those other solutions considered was the Android Volley library. Volley was introduced by

Android in 2013 to make networking calls faster and easier. It offers many features but it was not possible to explore all of them in the given timeframe. A lot of documentation was found around 2013 when it was introduced but subsequent to that found to be lacking. Volley has a response listener and an error listener to deal with both cases. It was possible to easily and quickly access API data in both JSON and XML formats and parse it. Ultimately the decision was taken to revert from using Volley back to downloading files individually because it was proving difficult to manage the volley requests and ensure the synchronous unfolding on the application's processes. Despite mobile resource limitations, due to the small amount of data currently being downloaded, any potential negative impact of this approach has to date not been noticeable.

5.5.4 Parsing Data

The Xml Pull Parser was used because it is recommended by the Android Developers training manual. It is described as an efficient and maintainable way to parse XML on Android.

5.6 Key Functionality

5.6.1 Alarm Manager

The Android Alarm Manager class provides for a system wakeup control, so it possible for the alarm to initiate services for an application that is not currently in use. One aim of the application is to limit the dissemination of information to the user's preferred time. The Clear Skies application lets the user decide when they want the background check to take place. In this way polling is avoided and the payload is reduced.

The Android Job Scheduler API was considered as an alternative. Given time constraints and the need to test the impact of batch job processing on the application, it was not implemented at this point in the project (Vogella, 2016).

5.6.2 Intent Service

To provide a good user experience all potentially slow running operations (such as location and network access) in an Android application should run asynchronously.

As of Android 3.0 (Honeycomb), attempting network access on the main UI thread causes the system to crash with a NetworkOnMainThreadException exception (Vogella, 2016).

An IntentService is a hybrid of a thread and a service. The IntentService handles the opening of the thread, and closes it once the processes required of it are complete. The work in the IntentService can take place when the application is not in the foreground, a feature which is essential for the Clear Skies application.

The Android AsyncTask class was considered briefly as a solution however deemed unsuitable because it is not possible for the work in the instance of AsyncTask to be undertaken when the UI is not active. Handlers provide another potential solution but the IntentService class ultimately benefits from the advantages of it being an extension of the Android Service class – it works in tandem with the AlarmManager to schedule tasks and makes an app less likely to be killed by putting it priority-wise between foreground and background apps (Android Developers 2016).

5.6.3 Broadcast Receiver

The main "ClearSkiesService" Intent Service manages the network activities for the application. BroadcastReceivers provide crucial communication between those network activities. It is not possible to register a Broadcast Receiver within an Intent Service, so inner class BroadcastReceivers were implemented and made static in order to be seen in the manifest. The receivers and their corresponding Intent Filters were both registered in the manifest.

Given that the broadcasts that are made do not need to be accessed outside of the application itself, implementation of Local Broadcast Receivers would improve the efficiency of this approach and will be considered in further project development.

5.6.4 Default Shared Preferences

The Android Preference Manager class has been used to access the default file that is used by the preference framework to store user preferences. The small amount of data needed to record user preferences and location coordinates are stored in this file.

5.6.5 Time

All Unix timestamps have been treated to ensure that Daylight Savings is taken into account.

5.7 Updating the UI

The UI is directly impacted by the results of the downloaded data, but only a small part of it is populated with data received from the server, and only when certain conditions are met. The singleton pattern has been used to provide the data that updates the UI. Depending on the outcome of the background work, Array Lists made accessible to the whole application are updated with text to be applied to the UI's Text Views. These Array Lists feed a custom-made Adapter, which applies the appropriate format to each List View item before updating the UI in one go. The Array Lists are updated in the Intent Service but accessed in the Main Activity to update the UI, because it is not possible to update the UI directly from an Intent Service. Access to the Array Lists is synchronized to ensure that only one thread can access these shared objects at a time. Array Lists were chosen because they can grow and reduce in line with the number of List Items required by the application. Furthermore the simple Array List *clear* method quickly empties the Array Lists before they are repopulated with fresh data.

Future development of the app is scheduled to include a database that would be connected to the FCM and would supply a Cursor Adapter with data to update the UI accordingly. As an interim measure, the functionality of a Matrix Cursor was explored. It affords a locally stored database that can supply the Cursor Adapter but did not provide the flexibility of Array Lists to shrink in size and be cleared and repopulated.

5.8 Activity Lifecycle and Killing Apps

Android kills low priority apps that haven't been used in a while, or any lower priority apps if required in order to maintain a responsive foreground app, so the Clear Skies app needs to manage this. By implementing Intent Services to carry out background work, the app remains in a state between foreground and background, which although not guaranteed, is less likely to be killed. The app has been developed for Gingerbread devices and above, so it is possible due to old Android

practices that in older devices that Clear Skies can be killed from *onPause* in the activity lifecycle, depending on the host device. Since Honeycomb apps can rely on *onStop* being called before system terminates the app. One measure is to close all connections in the *onPause* & *onStop* state to improve chances of the app not being killed.

The manifest permissions allow the Alarm Manager to continue to fire after a device has been rebooted.

5.8.1 Coding for Battery Life

Key implementations have been made as recommended by the 2009 Google IO event "Coding for Life—Battery Life, That Is" (Sharkey, 2009). Although this documentation is over seven years old, many of the key issues remain in sync with more recent Android documentation.

Clear Skies checks for a network connection and waits for 3G/ 4G or Wi-Fi before trying to start its work. Efficient data formats and parsers have been selected and View recycling using List View has been implemented. In terms of location, the app tolerates coarse location results using network because it is much cheaper than using GPS. The Broadcast Receivers are dynamically enabled and disabled in the manifest and the Alarm is set to *Inexact Repeating* so it wakes up to combine updates with other applications. Refactors of existing code are required to ensure its efficiency and the recycling of Java objects where possible. Currently the application does not check device battery state before undertaking its daily background activity.

5.8.2 Managing Network Usage

By using the Android Connectivity Manager class, the Clear Skies application listens for system broadcasts that alert the application to the network connectivity available and respond accordingly. The app does not currently perform extensive network operations, so it does not provide the user with fine-grained control over the network resources. If either Wi-Fi or network data are accessible, the application uses it to perform its tasks. In the future it will be important to reconsider this design after analysis of the application's power consumption and other factors. Options include allowing the user to select the type of connection they find acceptable, given that metered data is often more expensive and limited. Furthermore, the application

can be set up to cease its background activities if the device runs low on battery. This potentially provides a sympathetic response to wider user requirements that makes the app user-friendly.

5.9 Conclusions

Managing the project with Product Backlog and UML tools proved to be very useful. It helped maintain focus on both deadlines and the specific specification. Git provided an effective version control system, that once familiar with, allowed more freedom to change and break the code. Development of features took longer than anticipated initially but tracking progress enabled this to be taken into account as the project progressed.

The training guides provided by Android proved to be very helpful.

Most rewarding is the scope for scalability that the project clearly demonstrates. Future development is further explored in final chapter of this report.

Testing and Evaluation

6.1 Introduction

During the development of the project, assessment and evaluation of the system architecture and UI design was carried out continually. In the course of these evaluations, numerous alterations were made. Ultimately though, the prototype has not diverged greatly from its imagined form at the outset of this process. The presented software solution exists as a tangible demonstration of the system design, providing a proof of concept that is easy to understand.

In the pursuit for validation, the prototype app was distributed to a number of willing participants to find out if it met the operational needs of a user.

6.2 Testing

6.2.1 Verification

The Clear Skies prototype was developed using a Samsung Galaxy SIII, Device: GT-I9300, Android version: 4.3.

Unit testing and incremental integration was on going throughout the implementation process. Often it was easier to implement a feature by trying out and testing a piece of code on its own before adding it to the growing application and testing it there. Logs have proved essential to this project. Given that so much of the work undertaken by the system is not visible on the UI, logs have been relied upon heavily to follow the flow of processes, to detect errors and to verify the application logic. Figure 21 shows the application being opened and used for the first time. The default Checking time is *20:00*. The user updates it to the time *22:30*. The main UI is updated accordingly with "*Next Update 22:30*".

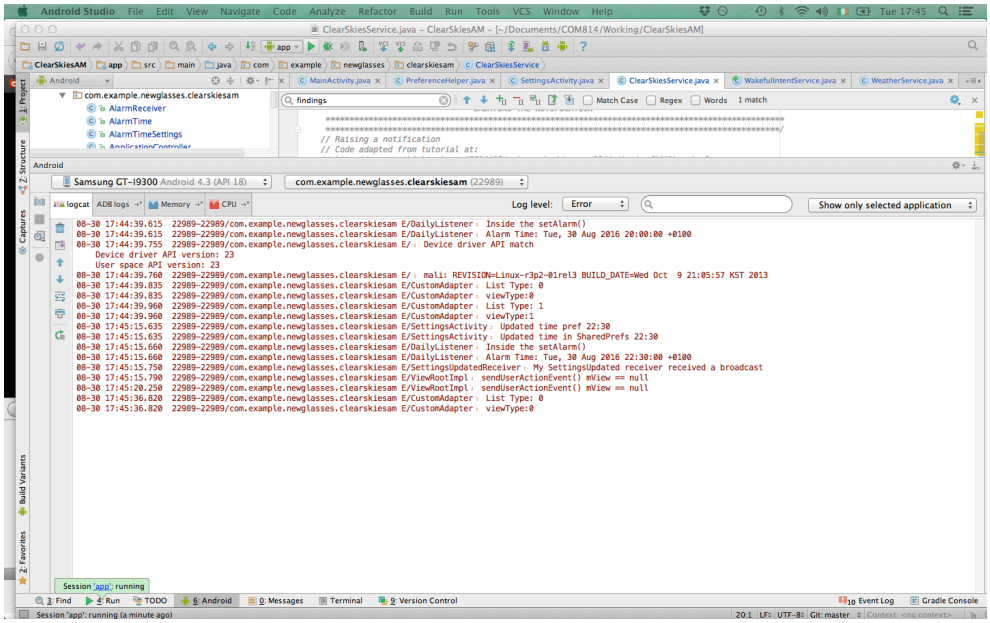


Figure 21: *Changing the Checking Time*

Figure 22 continues the user interaction. The user clicks the *Refresh* button and the background services begin. The device coordinates are retrieved, verified, converted into text and used to query the weather. The skies are not forecast to be clear so the background work ends and the UI is updated to inform the user of "*Nothing to Declare*". The *dataToDisplay arraylist* summarised the results returned from the background work, in this case the device coordinates, and an unsuccessful weather result. The *List Type* and *viewType* show how the different List View layouts are differentiated when updating the UI.

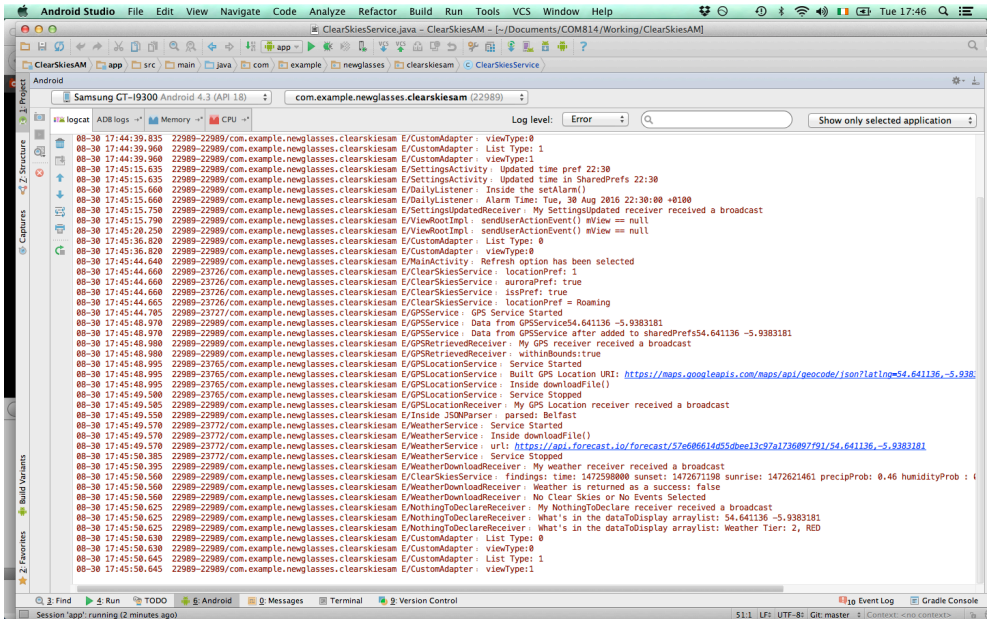
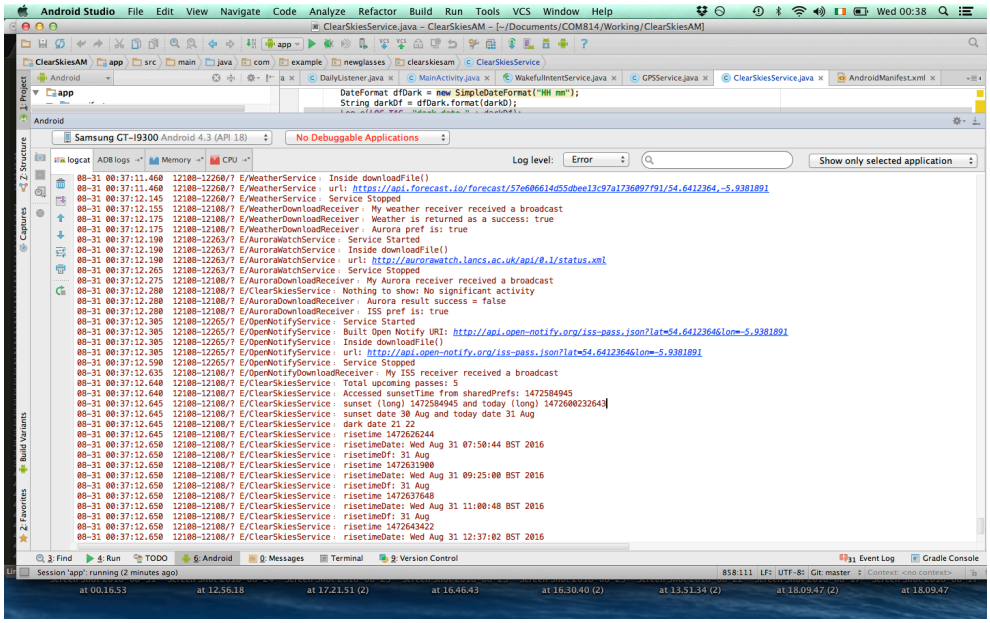


Figure 22: *Clicking the* ***Refresh*** *button*

Forcing the weather result to be successful is the best way to see what the background work can return. Figure 23 shows a forced weather success result and the resulting data returned by the Aurora and ISS Intent Services. Aurora displays "No Significant Activity" and none of the ISS pass overs occur between sunset and sunrise on the day of the query.



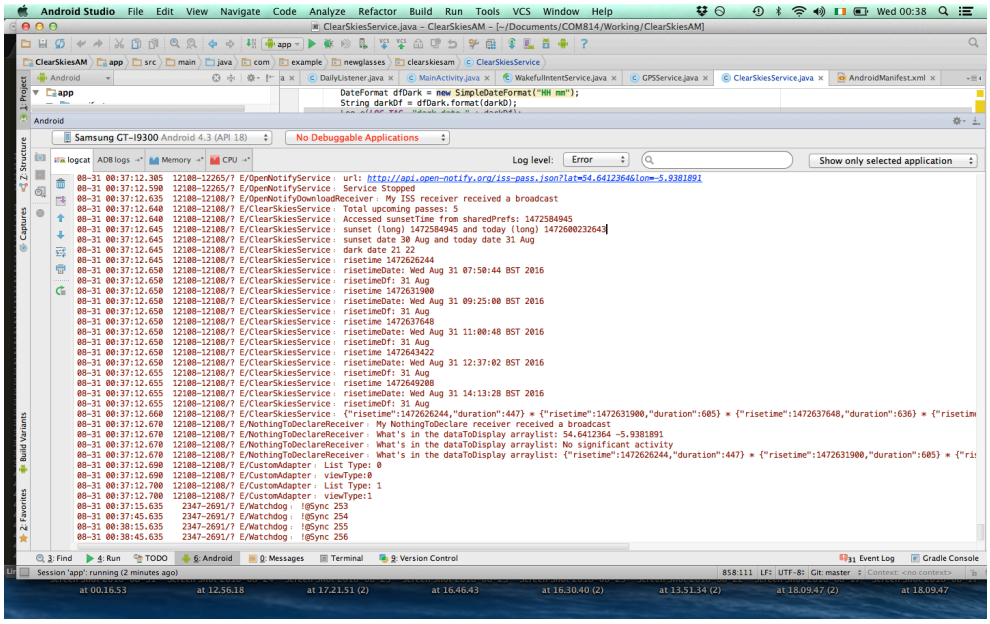


Figure 23: *Forced Weather Success*

The integration test log can be found in Appendix N. It details the scenarios used to determine whether or not the individual units of the system worked together, once the minimum viable prototype was implemented.

6.2.2 Validation

To undertake system and acceptance testing, the application was built into a signed .apk file and distributed to a number of potential users. The interested members of the NIAAS were contacted as well as some individuals who offered to test the application. One member of the NIAAS was available to test the system. Another member, Ken McCaw, made contact. Although unable to take part in testing because it was restricted to Android, he expressed interest in the idea itself:

> "I think the idea is great and would love to be involved with it."

In total five individuals took part and completed focus group questionnaires. All of the participants had beginner level/ no experience except one participant who identified himself as an intermediate observer. The software and associated literature was distributed via email. This was a deliberate decision to see how users responded to the application without prompting from someone with knowledge of the inner workings of the app. Participants were encouraged to use the application for a week, although dependent on their schedules they used the app for varying amounts of time. The focus group questionnaire and results can be found in Appendix O. Google Forms was used to make the questionnaire.

In terms of outcomes, four of the five participants were able to download and use the application. It was perhaps a disadvantage to not be present for the testing, or to have presented the application and explained the questionnaire in person. One person indicated that they had received a notification but on further investigation it transpired that they were referring to an updated UI that notified them of *"Nothing to Declare".*

For one participant the app crashed repeatedly when she tried to use it. The device it was installed on the Marshmallow operating system. To date Clear Skies does not take into account user location permissions for Marshmallow and above. Since

Marshmallow, due to privacy issues, location permission checks in Android are made dynamically (not when the application is first installed). This is a possible cause of the error. Further testing in both of these cases is required to fully understand the problems that arose.

Navigation and UI design of the application received positive feedback, the only negative coming from the participant for whom the application crashed. In terms of accessibility, one participant remarked that it was possible to read the screen text without glasses.

Participants rated the importance of additional features. The follow list displays on average (mean) the order of preferences, from most important to least important:

1. More detail about events
2. Implementing a Checking Time range rather than one specific time
2. Widen the range of celestial events covered by the app
3. Inputting a specific location
4. More detail about the weather
5. Extend the app to work outside the UK
5. Detail about how to find the events in the night sky
6. Explicit button in the settings to turn off (and back on) the daily background check

In the time period, it was not possible to deal with all of the user stories that arose from the Clear Skies Application Research Questionnaire. Key requirements were prioritised to ensure the delivery within timescales of a viable prototype that displays proof of concept. It is valuable to be able to compare those requirements with the feedback provided from the focus group as it will help to inform future development of the application.

In order to properly test the prototype, it should be tested and observed over a much longer period of time. It is important to see how the system responds to prolonged user testing and changing real-world weather and astronomy conditions.

According to the website Software Testing Help, effective testing requires access to the right mobile devices or simulators. It is also advised that specific mobile app tests should be undertaken in respect of battery usage, the speed of the application, its data requirements (for internet usage) and its memory requirement (Ratnakar N, 2015). Performance-related data is available through the Android Studio device monitor. It is possible to access the Hierarchy Viewer in order to determine the efficiency of Views and preferred coordinates can be supplied to a running emulator. Using the Dalvik Debug Montiro Server (DDMS) it is possible to work with the device's file system, monitor the impact of network usage on the device's battery.

6.3 Evaluation

From interacting with the application and the resources it uses, a number of observations have been made.

The Open Notify service does not always return data. Figure 24 below shows the application running with a forced (dummy) weather success. Both Aurora and ISS data is accessed but Open Notify does not return any information. It does not prevent the service from finishing but it shows how a back off and retry policy is essential for the application.

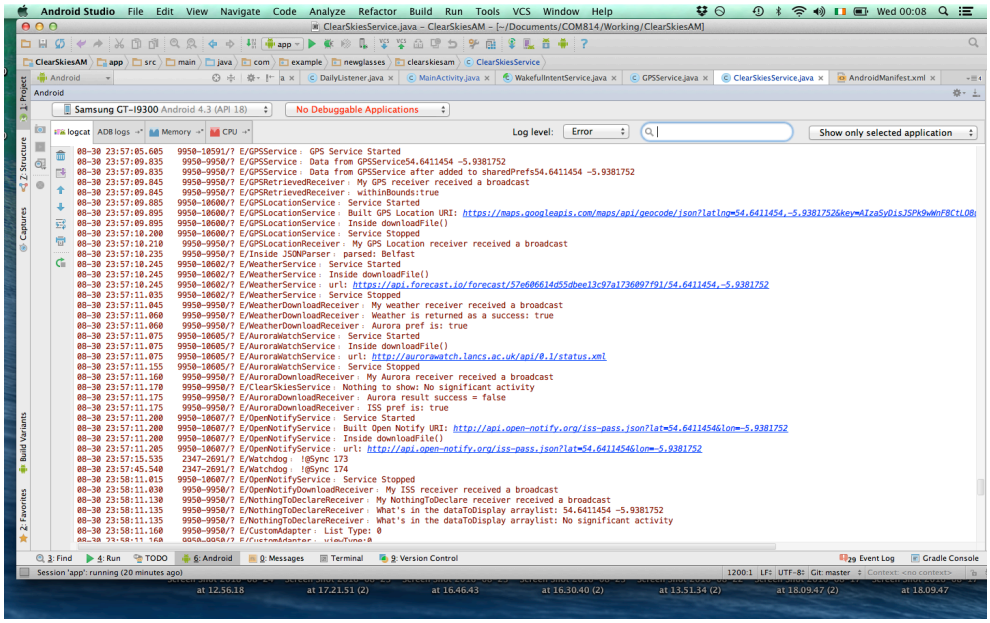


Figure 24: *Open Notify fails to return data*

Although an excellent and reliable source, AuroraWatch does not always provide accurate information. This is in part because it is attempting to measure a natural phenomenon and so there will always be a margin of error with such a service. The service they provide is automated in the first instance, and does not always elegantly deal with the nuances in results. This is likely to be the case for many celestial events, so it is important that the user is informed and prepared so they can engage with the application with the right expectations.

A rare occurrence happened during the testing phase. The AuroraWatch service sent out a red alert notification. This is the highest alert category, indicating that the aurora should be visible from most of the UK. Although it turned out to be a false alarm, it provided an opportunity to test out the Clear Skies app with a lesser-spotted result. Although the logs clearly show that the red alert was received, it was not recognised by the app as a successful aurora. The weather conditions were good

(amber). AuroraWatch rectified the alert a short time later. Figure 25 displays the logs.

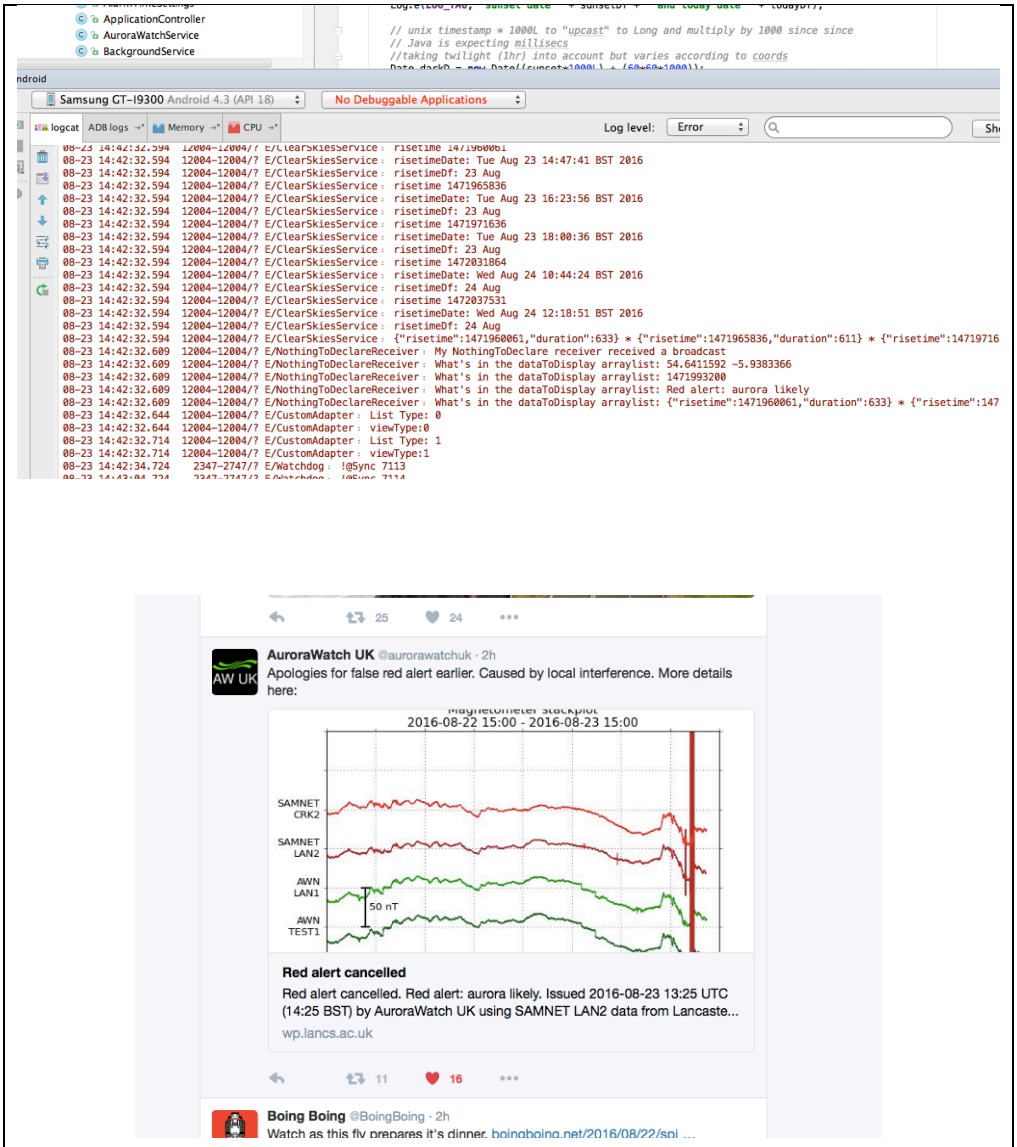


Figure 25: *AuroraWatch Red Alert*

This event highlights the importance of testing the application with real data if possible. It will take a long time for the data to appear naturally, which presents an

issue with testing. As well as observing the behaviour of the application and testing it over a long period such as a year (or more), it may be possible to recreate the downloaded files with dummy data. This would allow for more thorough testing of the application algorithms that analyse the data and potentially provide good preparation for the ultimate test case - when something exciting is visible in the night sky.

Conclusions and Recommendations

7.1 Key Findings

Approaching the project as someone with no prior background in the field of astronomy, it was beneficial to come to understand the scale of work required in order to become familiar with an unknown area even before approaching the problem or contemplating a solution. Fundamental to the project was the insight and opinion provided generously by individuals who had an interest in night time viewing, be it as a beginner or as an advanced observer.

The value and importance of defining a minimum viable prototype with prioritised extensions was clear throughout the project, as was the need to regularly revisit the release schedule and product backlog to ensure a prototype was produced within the timescale. By following the pattern of unit then integration tests, the code grew in a wieldy fashion.

Key to the Clear Skies project is the vast amounts of publically available astronomy data. The prototype demonstrates it is possible to build upon existing work that generates and/ or manipulates this data to create an intuitive and responsive software solution that provides its user only with the information that interests them, and only when it is pertinent to do so.

This type of interaction is somewhat at odds with the interaction both implicitly and explicitly encouraged by many well-known apps. They use notifications and other means to create habit-forming behaviour (Constine 2014) that increases user engagement with the app. As the Business Plan indicates, there is no requirement to boost advertising revenue or collect user data in the Clear Skies app. Instead of notifications being used to boost user engagement, the Clear Skies application is free to provide a low-profile service, reducing interaction to what is strictly necessary.

This use of mobile, coupled with a simple UI is influenced heavily by Weiser's idea to reverse the current, pushing computers into the background and help overcome information overload (Weiser 1999).

7.2 Future Development

The potential for future development of the Clear Skies application is significant and exciting. A key step in development is the realisation of features that were deemed in the implementation phase to support the functional requirements of the system. Examples include:

- A progress bar that indicates background work is being undertaken provides responsiveness and reassures the user.
- Default preferences indicated in the summary section of the Settings Activity to further clarify to users the default settings.
- The ability to clearly enable and disable the service gives users more control over how and when the application interacts with their device.
- Files held in internal storage should be deleted or overwritten.
- Persist data in the case of a successful Clear Skies result in both on and offline states by using saved instance state.
- Refactoring code to ensure that all opportunities to reuse and recycle are taken
- Informing users when they try to use the application that notifications are not switched on

Currently the application does not deal with failing to fix coordinates or failed network connection and transfer attempts. The GPS and API results form the backbone of the service the application provides and are essential for its reliability. Fundamental to future development is a successful retry and back off strategy that balances the requirement for a result with responsiveness of the app.

Further research into accessibility services offered by Android would increase the application's potential user-base further.

It is also essential that the project planning going forward is informed by:

- Outstanding functional requirements

- Revisiting outcomes of the original research questionnaire
- User stories that were collected but de-prioritised
- Information gathered from the first round of user testing

7.2.1 Wider Release

Before wider release, the application needs to be developed beyond the prototype phase to a robust application. This will also require extensive on going testing, particularly to ensure that the information the user receives is reliable and accurate.

The potential to connect FCM to third party data resources and avail of push notifications remains of great interest. The option to be able to push pertinent information to the device within a user-defined timeframe is appealing for a number of reasons. For one, in terms of API access, every call is not being made by every device using the application. If using FCM it will trigger the app even if its not running and using the cloud to build server-side logic is low cost and low maintenance. (Rodger 2011).

Currently Fragments have not been implemented and the device is fixed in portrait mode because it suits the layout design, and is common for smartphone use. Implementing fragments would allow the UI to elegantly fit a tablet screen if a user so wishes. Further investigation into the possibility of extending scope into wearables is also very appealing.

With the help of effective project management tools, this research project has resulted in the development of a viable Clear Skies prototype that provides great potential for scaling and growth.

References

Android Developers 2016, The Zen of IntentService
(Android Performance Patterns Season5, ep 7)
Retrieved 11th July 2016 from
https://www.youtube.com/watch?v=9FweabuBi1U

Android, Usability
Retrieved 19th March 2016 from
https://material.google.com/usability/accessibility.html#

Armagh Planetarium n.d., What do we do?
Retrieved 14th January 2016
From: http://www.armaghplanet.com/html/what_do_we_do.html

AstroGrid 2012, The Virtual Observatory Concept
Retrieved 13th January 2016
From: http://www.astrogrid.org/theVO.html

Beck, K et al. 2001, Manifesto for Agile Software Development
Retrieved 19th March 2016 from
http://www.agilemanifesto.org/

Berlind, D 2015, What exactly is an API?
Retrieved 20th January 2016
From: http://www.programmableweb.com/news/what-exactly-api/analysis/2015/12/03

Bowes, J 2015, Kanban vs Scrum vs XP – an Agile comparison
Retrieved 19th March 2016 from
https://manifesto.co.uk/kanban-vs-scrum-vs-xp-an-agile-comparison/

Boyd, M 2015, NASA Launches API Portal to Encourage Use of Data Sets
Retrieved 4th January 2016 from
http://www.programmableweb.com/news/nasa-launches-api-portal-to-encourage-use-data-sets/2015/05/26

Butler, C.J., García Suárez, A.M., Coughlin, A.D.S & Morrell, C 2005 Air temperatures at Armagh Observatory, Northern Ireland, from 1796 to 2002, International Journal of Climatology, Vol. 25, p. 1055-1079.
Retrieved 13th January 2016
From: http://adsabs.harvard.edu/abs/2005IJCli..25.1055B

Constine, J 2014, The Morality of A/B Testing
Retrieved October 11th, 2015 from
http://techcrunch.com/2014/06/29/ethics-in-a-data-driven-world/

Crawford, D.L. 2000, Light pollution, an environmental problem for astronomy and for mankind, Memorie della Societa Astronomica Italiana 01/2000; 71:11.
Retrieved 13th January 2016
From: http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?bibcode=2000MmSAI..71...11C&db_key=AST&page_ind=0&plate_select=NO&data_type=GIF&type=SCREEN_GIF&classic=YES

Darcey, L & Conder, S 2012, Android Wireless Application Development,
Volume II: Advanced Topics, Third Edition, Addison-Wesley, Indiana, USA

Dark Sky Discovery n.d., Where to see stars
Retrieved 18th January 2015
from: http://www.darkskydiscovery.org.uk/dark-sky-discovery-sites/map.html

Douglass, M 2015, 10 of the most breathtaking night skies on Earth
Retrieved 18th January 2016 from
http://www.bbc.com/earth/story/20150826-10-of-the-earths-starriest-skies

European Space Agency n.d., Rosetta Ground-Based Campaign
Retrieved 13th January 2016 from
http://rosetta.jpl.nasa.gov/rosetta-ground-based-campaign

Harvey, S. 2015, General Astronomy Links
Retrieved 18th January 2016 from
http://britastro.org/computing/data_catalogues.html

Herron, S 2012, Make Existing High-Value Data and Content Available through Web APIs
Retrieved 13th January 2016
From: http://www.nasa.gov/agency/digitalstrategy/section2.html

Hildebrand, C., Shankland, P. & Baya, Vinod 2011, Consumerization of APIs: Scaling integrations
Retrieved 20th January 2016 from
http://www.pwc.com/us/en/technology-forecast/2012/issue2/features/feature-consumerization-apis.html

Institution of Engineering and Technology n.d., The Internet of Me: Its all about my screens
Retrieved 13th January 2016
From: http://conferences.theiet.org/turing/

Jakuben, B 2014, The Beginner's Guide to Location in Android
Retrieved March 18th 2016 from
http://blog.teamtreehouse.com/beginners-guide-location-android

Kellingley, N n.d., What You Need to Know About Smartphones vs. Tablet use of the Mobile Internet
Retrieved 20th April 2016 from
https://www.interaction-design.org/literature/article/what-you-need-to-know-about-smartphones-vs-tablet-use-of-the-mobile-internet

Knapen, J.H 2011, Scientific collaborations in astronomy between amateurs and professionals, published in proceedings of "Stellar Winds in Interaction", editors T. Eversberg and J.H. Knapen
Retrieved 18th January 2016 from
http://arxiv.org/pdf/1101.0684v1.pdf

Kyba C. C. M., Ruhtz, T, Fischer J & Hölker, F 2012, Red is the new black: how the colour of urban skyglow varies with cloud cover, Monthly Notices of the Royal Astronomical Society, Vol. 425, Issue 1, pages 701–708.
Retrieved 13th January 2016 from
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2966.2012.21559.x/abstract

Lionbridge, 2012, Mobile Web Apps vs. Mobile Native Apps: How to Make the Right Choice
Retrieved 20th April 2016 from
http://www.lionbridge.com/files/2012/11/Lionbridge-WP_MobileApps2.pdf

Livesey, R. J. 1971, "The distribution of cloud and its effect on observing', Journal of the British Astronomical Association, Vol. 81, p. 292 – 294
Retrieved 13 January 2016 from
http://adsabs.harvard.edu/full/1971JBAA...81..292L

Llewellyn, A 2015, SkyWatch: An API for the Universe
Retrieved April 5th, 2016 from
https://open.nasa.gov/blog/skywatch-an-api-for-the-universe/

Maeda, J 2006, The Laws of Simplicity, MIT Press, MA, USA

McKevitt, G 2013, NI space industry ready for liftoff.
Retrieved 11th January 2016 from
http://www.bbc.co.uk/news/uk-northern-ireland-24728286

McNally, C 2013, How Color Contrast for Accessibility Helps Mobile Experience
Retrieved August 10th 2016 from
https://www.phase2technology.com/blog/color-contrast-for-accessibility-benefits-your-mobile-experience/

Microsoft Visual Studio 2012, Test Early and Often
Retrieved 19th March 2016 from
https://msdn.microsoft.com/library/ee330950(v=vs.110).aspx

Moggridge, B. (2006) Designing Interactions. Cambridge, MA: The MIT Press

NASA APIs n.d., About
Retrieved 13th January 2016 from
https://api.nasa.gov/index.html#about

NASA International Space Apps Challenge, Spot the Station.
Retrieved 15th June 2016 from
https://2013.spaceappschallenge.org/challenge/spot-the-station/

Nasmul 2010, Android Location Providers –gps, network, passive – Tutorial
Retrieved July 30th 2016 from
http://developerlife.com/tutorials/?p=1375

Norman, D.A. (2004) Emotional Design: Why We Love (or Hate) Everyday Things, Basic Books, New York.

Northern Ireland Executive 2015, Major £6m LED street lighting pilot scheme for Banbridge and Craigavon.
Retrieved 18th January 2016 from
http://www.northernireland.gov.uk/news-major-6m-led

Prusty, N 2015, Overview of Intel XDK
Retrieved 20th April 2016 from
http://www.codeproject.com/Tips/883716/Overview-of-Intel-XDK

Pallé, E. & Butler, C.J. 2001, Sunshine records from Ireland, cloud factors and possible links to solar activity and cosmic rays, DOI: 10.1002/joc.657
Retrieved 18th January 2016 from
http://star.arm.ac.uk/~ambn/344cjb.pdf

Pstatz, 2010, Get Started With Rest
Retrieved August 10th, 2016 from
http://www.webmonkey.com/2010/02/get_started_with_rest/

Ratnakar, N 2015, Beginner's Guide to Mobile Application Testing
Retrieved 20th January 2015 from
http://www.softwaretestinghelp.com/beginners-guide-to-mobile-application- testing/

Rebecca, 2012, iPhone Accessibility: White Text on Black Background
Retrieved August 10th, 2016 from
http://blog.literaryspring.com/2012/11/iphone-black-background/

Rincon, P 2006, Telescopes 'worthless' by 2050.
Retreived 18th January 2015 from
http://news.bbc.co.uk/1/hi/sci/tech/4755996.stm

Rodger, R 2011, Beginning Mobile Application Development in the Cloud Rodger, Wrox Publishing, UK

Rogers, S. 2009, UK population data: how fast is it increasing?
Retrieved 18th January 2016 from
http://www.theguardian.com/news/datablog/2009/oct/21/uk-population-data-ons

Royal Astronomical Society n.d., British Astronomy - Theory, Radio and Space Astronomy
Retrived 13th January 2016 from
https://www.ras.org.uk/education-and-careers/208-miscellaneous/912-british-astronomy-theory-radio-and-space-astronomy

Sharkey, Jeff 2009, Coding for Life—Battery Life, That Is"
Retrieved 10th August 2016 from
http://docs.huihoo.com/google/io/2009/W_0300_CodingforLife-BatteryLifeThatIs.pdf

Shneiderman, B 1986, Eight Golden Rules of Interface Design
Retrieved 21st April 2016 from
https://faculty.washington.edu/jtenenbg/courses/360/f04/sessions/schneidermanGoldenRules.html

Solar Eclipse, Jupiter watch and Stargazing live at Queen's 2015
Retrieved 17th January 2016 from
https://star.pst.qub.ac.uk/wiki/doku.php/blog/2015113015h37m11s_solar_eclipse_jupiter_watch_and_stargazing_live_at_queen_s

Statista 2016, Number of smartphone users in the United Kingdom (UK) from 2011 to 2018 (in millions)
Retrieved 15th January 2016 from
http://www.statista.com/statistics/270821/smartphone-user-in-the-united-kingdom-uk/

The World Wide Web Consortium (W3C), Designing for Inclusion
Retrieved 19th March 2016 from
http://www.w3.org/WAI/users/Overview.html

The World Wide Web Consortium (W3C), Web Content Accessibility and Mobile Web: Making a Website Accessible Both for People with Disabilities and for Mobile Devices
Retrieved 19th March 2016 from
http://www.w3.org/WAI/mobile/overlap

Udacity, Developing Android Apps, Built by Google
Retrieved 22nd March 2016 from
https://www.udacity.com/course/developing-android-apps--ud853

Udacity, How to Use Git and GitHub
Retrieved 24th March 2016 from
https://www.udacity.com/course/how-to-use-git-and-github--ud775

Udacity, Software Development Process, Built by Georgia Tech
Retrieved 22nd March 2016 from
https://www.udacity.com/course/software-development-process--ud805

Vogella, 2016 Android Networking - Tutorial
Retrieved August 10th from
http://www.vogella.com/tutorials/AndroidNetworking/article.html

Vogella, 2016 2. Using the JobScheduler to schedule background jobs
Retrieved 10th August 2016 from
http://www.vogella.com/tutorials/AndroidTaskScheduling/article.html#options-for-scheduling

Wagner, J 2014, Top 10 Weather APIs
Retrieved 14th January 2016 from
http://www.programmableweb.com/news/top-10-weather-apis/analysis/2014/11/13

Wagner, J 2015, Top Weather APIs: An In-Depth Comparison
Retrieved 14th January 2016 from
http://www.programmableweb.com/news/top-10-weather-apis/analysis/2014/11/13

Wasserman, A 2010, Software Engineering Issues for Mobile Application Development
Retrieved 20th April 2016 from
https://www.cmu.edu/silicon-valley/wmse/wasserman-foser2010.pdf

Weiser, M 1999, The Computer for the 21st Century
Retrieved 15th April 2016 from
http://scisweb.ulster.ac.uk/~derek/com811_2016/Reading2016/weiser.pdf

Imagery

Star imagery in the main UI
http://40.media.tumblr.com/e6896b40e5164dfaf4922f6702dbb3c3/tumblr_msxopq8JKq1rmdrjqo1_250.png

Overlay imagery
http://4.bp.blogspot.com/-7UCdNj6zJ6Y/Uiu3vQPWarI/AAAAAAAABmQ/Oz4yw8m3TQw/s1600/rainbow_glitter_png_by_maddielovesselly-d6cgjtx.png

Refresh and Settings icons
Taken from the Android Material Icons collection
https://design.google.com/icons/index.html

Clear Skies Logo
Gill Sans font, typeface Regular, White

Appendices

Appendix A	Clear Skies Mobile Application Research Questionnaire
Appendix B	Clear Skies Research Questionnaire Results
Appendix C	Clear Skies Research Questionnaire Main Findings
Appendix D	APIs: Publically Available Astronomy Resources
Appendix E	APIs: Market research of existing established weather APIs
Appendix F	NIAAS participants Recommended Astronomy Apps and the corresponding market research
Appendix G	Main findings of the Functional Requirements section of the Clear Skies questionnaire
Appendix G	Functional Requirements
Appendix H	Non-functional Requirements
Appendix I	Clear Skies Product Backlog
Appendix J	Clear Skies User Cases
Appendix K	United Kingdom Latitude & Longitude Map
Appendix L	Clear Outside Astronomer Forecast: Estimated Traffic Light Bounds
Appendix M	UML Diagrams (Selected, Ongoing)
Appendix N	Integration Test Log
Appendix O	Clear Skies Prototype Testing: Focus Group Questionnaire and Results

Appendix A

Clear Skies Mobile Application Research Questionnaire

Q1

Please indicate your level of interest in and knowledge of astronomy.

Tick the box that best applies to you:

☐ I am interested in astronomy but have never pursued it
☐ I am a beginner observer
☐ I am an intermediate observer
☐ I am an experienced observer
☐ I am an Astronomy professional

Q2

Have you ever used a mobile application to help you explore the night skies?
If so, what resources have you used/ would you recommend?

Tick the box that best applies to you:

☐ I have never used a mobile application astronomy resource
☐ I occasionally use a mobile application astronomy resource
☐ I regularly use a mobile application astronomy resource

Tick the boxes that apply to you:

Mobile App	**Aware of**	**Used**	**Recommend**
Sky View Café	☐	☐	☐
PocketSky	☐	☐	☐
The Night Sky	☐	☐	☐
Heavens Above	☐	☐	☐
Stellarium Mobile Sky	☐	☐	☐

Other app(s) I would recommend:

Q3

Do you have a preferred weather website or app when checking for clear skies?

Tick the boxes that apply to you:

Website	**Aware of**	**Used**	**Recommend**
Xcweather.co.uk	☐	☐	☐
Metcheck.com	☐	☐	☐
Bbc.com/weather	☐	☐	☐

Other website(s) I would recommend:

Q4

Where do you obtain information about what is currently observable in the night sky?

Tick the boxes that apply to you:
- ☐ NI Amateur Astronomy Society
- ☐ Armagh Planetarium
- ☐ SkyMaps.com
- ☐ EarthSky.org
- ☐ Newspaper articles
- ☐ Word of mouth
- ☐ Don't know/ don't research

Other (please state):

Q5

How far do you usually travel to avoid light pollution?

Tick the box that applies to you:
- ☐ Less than 1 mile
- ☐ Less than 5 miles
- ☐ Less than 10 miles (see over page)
- ☐ Less than 20 miles
- ☐ 20 miles or more
- ☐ Don't know

Q6

How much notice would you require in advance of notification of good visibility to view astronomical phenomena?
(Please remember the closer the event, the more accurate the weather forecast)

Please tick all that apply to you:
- ☐ from 4 hours
- ☐ from 2 hours
- ☐ from 1 hour
- ☐ less than an hour
- ☐ Don't know

Q7

Would you find a monthly calendar overview of astronomical phenomena useful?
- ☐ Yes
- ☐ No
- ☐ Don't know

Q8

Would you find a location changer useful (e.g. for going on holiday)?
- ☐ Yes
- ☐ No
- ☐ Don't know

Q9

Which astronomical phenomena would you be interested in receiving notifications about via the Clear Skies app?

Tick all that apply:

	Interesting	**Not Interesting**	**Don't know**
Sun	☐	☐	☐
Planets	☐	☐	☐
Moon	☐	☐	☐
Stars and Constellations	☐	☐	☐
Comets	☐	☐	☐
Asteroids	☐	☐	☐
Meteors	☐	☐	☐
Deep Sky	☐	☐	☐
All of the above	☐	☐	☐

Other (please state):

Q10

What extra information would be useful as part of the Notification Badge for the Clear Skies App?

Tick all that apply:

- ☐ An image of the astronomical phenomena
- ☐ A short description of the astronomical phenomena
- ☐ A short history of the astronomical phenomena
- ☐ How the event can be viewed (naked eye, binoculars, telescope)
- ☐ Predicted amount of time the phenomena will be visible
- ☐ How to find the phenomena in the sky
- ☐ All of the above
- ☐ None of the above

Other (please state):

Q11

Have you got any other suggestions for features that would enhance the functionality of the Clear Skies App?

If you are happy to be contacted with further questions relating to the project including app testing, please provide your full name and email address here:

Thank you very much for your feedback!

Appendix B

Clear Skies Mobile Application Research Questionnaire Results

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Totals	%
Level of interest in and knowledge of astronomy																	
Interested but never pursued		1								1				1		3	20
Beginner observer	1		1	1		1	1				1				1	7	46.7
Intermediate observer					1			1	1			1				4	26.7
Experienced observer													1			1	6.7
Professional																	
Have you ever used a mobile app to explore the night skies?																	
Never		1	1					1		1						4	26.7
Occasionally	1						1							1	1	4	26.7
Regularly				1	1	1			1		1	1	1			7	46.7
Sky View Café																	
Aware of	1											1				2	13.3
Used																0	0.0
Recommend																0	0.0
PocketSky																	
Aware of	1											1				2	13.3
Used			1													1	6.7
Recommend																0	0.0
The Night Sky																	
Aware of						1										1	6.7
Used												1			1	2	13.3
Recommend														1		1	6.7
Heavens Above																	
Aware of																0	0.0
Used	1				1							1				3	20.0
Recommend													1			1	6.7
Stellarium Mobile Sky																	
Aware of				1												1	6.7
Used			1			1			1							3	20.0
Recommend	1				1								1			3	20.0
Other (Recommended)			Google Sky	Sky Safari					Star Map		Celestron SkyPortal	Star Walk	Sky Map				
Preferred weather app to check for clear skies?																	
xcweather.co.uk																	
Aware of	1											1				2	13.3
Used																0	0.0
Recommend											1					1	6.7
metcheck.com																	
Aware of	1											1				2	13.3
Used					1	1			1						1	4	26.7
Recommend								1			1					2	13.3
bbc.com/weather																	
Aware of														1	1	2	13.3
Used		1			1	1			1			1	1			6	40.0
Recommend	1		1					1			1					4	26.7
Other (Recommended)	Clear Outside - First Light Optics				Accuweather						NIAAS	Accuweather			Accuweather		
Where do you obtain information about what is currently observable in the night sky?																	
NI Amateur Astronomy Society	1	1			1	1	1		1		1	1	1			9	60.0
Armagh Planetarium	1						1				1		1			4	26.7
SkyMaps.com									1		1					2	13.3
EarthSky.org																0	0.0
Newspapaer articles											1				1	2	13.3
Word of mouth												1		1	1	3	20.0
Don't know/ don't research			1							1						2	13.3
Other		Sky At Night Magazine		Sky Safari	Stellarium	Astronomy Forums		Planisphere and Stellarium				Facebook					

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Totals	%
Level of interest in and knowledge of astronomy																	
Interested but never pursued		1								1				1		3	20
Beginner observer	1		1	1		1	1				1				1	7	46.7
Intermediate observer					1			1	1			1				4	26.7
Experienced observer													1			1	6.7
Professional																	
How far do you usually travel to avoid light pollution?																	
Less than 1 mile				1		1		1								3	20.0
Less than 5 miles	1		1				1									3	20.0
Less than 10 miles																0	0.0
Less than 20 miles		1							1							2	13.3
20 miles or more					1					1	1	1	1			5	33.3
Don't know														1	1	2	13.3
How much notice would you require in advance of notification of good visibility to view astronomical phenomena?																	
From 4 hours			1		1			1			1					4	26.7
From 2 hours	1			1					1	1			1	1	1	7	46.7
From 1 hour		1					1									2	13.3
less than 1 hour						1						1				2	13.3
Don't know																0	0.0
Would you find a monthly calendar overview of astronomical phenomena useful?																	
Yes	1	1	1	1	1	1	1	1	1	1		1	1			12	80.0
No											1					1	6.7
Don't know														1	1	2	13.3
Would you find a location changer useful (e.g. for going on holiday)?																	
Yes	1	1	1	1	1			1	1	1	1	1	1	1	1	13	86.7
No																0	0.0
Don't know						1	1									2	13.3
Which astronomical phenomena would you be interested in receiving notifications about via the Clear Skies app?																	
Sun													1			1	6.7
Planets		1	1		1			1	1				1		1	7	46.7
Moon									1				1		1	3	20.0
Stars and constellations		1	1		1				1				1		1	6	40.0
Comets		1	1					1	1	1			1		1	7	46.7
Asteroids			1					1	1						1	4	26.7
Meteors			1						1				1		1	4	26.7
Deep Sky					1			1					1		1	4	26.7
All of the Above	1			1		1	1				1	1		1		7	46.7
Other											Satellites						
What extra information would be useful as part of the Notification Badge for the Clear Skies app?																	
An image of the astronomical phenomena	1	1	1	1		1			1						1	7	46.7
A short description of the astronomical phenomena	1	1		1		1			1					1	1	7	46.7
A short history of the astronomical phenomena							1							1		2	13.3
How the event can be viewed (naked eye, binoculars, telescope)	1	1		1		1	1	1	1	1				1	1	10	66.7
Predicted amount of time the phenomena will be visible	1	1		1		1	1	1	1	1				1	1	10	66.7
How to find the phenomena in the sky	1	1		1	1	1			1	1				1	1	9	60.0
All of the above											1	1	1			3	20.0
None of the above																0	0.0
Other																	
Any other suggestions for the features that would enhance the functionality of the Clear Skies app?																	
	Clear Outside - First Light Optics	Sellarium Occular View	Moon phase								Aurora Predictions						

Appendix C

Functional Requirements - Main findings from the Clear Skies Mobile Application Research Questionnaire Results (Q5 – Q11)

Q5	***How far do you usually travel to avoid light pollution?***
	20% of people surveyed travel less than a mile to avoid light pollution, while approximately 46% travel 10 miles or more.
Q6	***How much notice would you require in advance of notification of good visibility to view astronomical phenomena?***
	Just under half of the people survey requested from 2 hours advance notice, approximately another quarter of those survey requested from 4 hours advance notice.
Q7	***Would you find a monthly calendar overview of astronomical phenomena useful?***
	80% of those surveyed said yes. Of those remaining, one person said no and two people said they did not know.
Q8	***Would you find a location changer useful (e.g. for going on holiday)?***
	Thirteen of the fifteen people surveyed said yes, the remaining two people did not know.
Q9	***Which astronomical phenomena would you be interested in receiving notifications about via the Clear Skies app?***
	Approximately 47% of those people surveyed indicated that the range of celestial events and objects provided would be of interest. *Of those remaining, the sun and moon were of the least interest, comets and planets proved to be the most interesting.*
Q10	***What extra information would be useful as part of the Notification Badge for the Clear Skies App?***
	Ten of the fifteen people surveyed felt that how the event can be viewed (naked eye, binoculars, telescope) and the amount of time the phenomena will be visible for would be useful on the notification badge. 9 people indicated that to find the phenomena in the sky would be useful.
Q11	***Have you got any other suggestions for features that would enhance the functionality of the Clear Skies App?***
	- The Clear Outside website (www.clearoutside.com) which provides weather forecasts tailored specifically to the needs of astronomers. - Stellarium Ocular View provides astronomers with the opportunity to view a 3D virtualisation of a particular object through the lens of specific ocular equipment such as telescopes. - Moon Phases are important because they also affect the visibility of objects and events in the night sky.

Appendix D

Publically Available Astronomy APIs

Astronomy API	Detail
Cerridwen	Solar system data suitable for astronomical and astrological purposes. Includes planets.
NASA Asteroids – NeoWs	Details near-Earth asteroids
NASA & American Museum of Natural History Star-API	Star position, luminosity, colour. Constellations. Planets. Star clusters.
Astrocast http://astrocast.org	Bitesize astronomy knowledge.
Predict the Sky http://predictthesky.org	Space events and global weather data. Work in progress.
Space Track www.space-track.org	Space objects and events including satellites.
SkyWatch app.skywatch.co/	Real-time updates of celestial events as they happen
AuroraWatch http://aurorawatch.lancs.ac.uk/api_info/	Provides real-time alerts of when the aurora is likely to be seen from the UK
Open-Notify http://open-notify.org	Provides overhead pass predictions for the International Space Station (ISS)
N2YO http://www.n2yo.com/api/	Satellites database
Where the ISS at? http://wheretheiss.at/w/developer	Current, past, or future position of the ISS

Appendix E

APIs: Market research of existing established weather APIs

Weather API	Detail
AccuWeather.com	Suggested in the NIAAS survey Does not have a free API
Wunderground.com	Suggested by Dr Giuseppe Trombino, University of Ulster. Detailed website includes pressure, visibility, cloud cover, humidity Free account offers: 500 calls per day, 10 per minute
Forecast.io (The Dark Sky Forecast API)	Powers the Clear Outside website Free account offers: 1,000 calls per day, every API thereafter costs $0.0001 each. They must be credited if you use their API JSON server.
OpenWeatherMap.org	Free: No more than 60 calls per minute and no more than 50,000 calls per day
WorldWeatherOnline.com	Free: No more than 250 calls per day

Appendix F

NIAAS participants Recommended Astronomy Apps and the corresponding market research as at 22nd January 2016

Recommended by NIAAS Questionnaire Participants		
Astronomy Mobile Apps	Online Weather Forecast	Astronomy Resources
The Night Sky	xcweather.co.uk	NIAAS
Heavens Above	metcheck.com	Armagh Planetarium
Stellarium Mobile Sky	bbc.com/weather	BBC Sky at Night magazine
Sky Safari	accuweather.com	Sky Safari
Star Map	clearoutside.com	Stellarium
Star Walk		Astronomy Forums
Celestron SkyPortal		Planisphere
Google SkyMap		Facebook

	The Night Sky	Heavens Above	Stellarium Mobile Sky	Google Sky Map	Sky Safari	Star Map	Star Walk	Celestron SkyPortal
iOS	✓	✗	✓	✗	✓	✓	✓	✓
Android	✓	✓	✓	✓	✓	✓	✓	✓
Cost	£0.99	FREE	£2.29	FREE	£2.29	£3.99	£2.29	FREE
In-App purchases	✓	✗	✗	✗	✓	✗	✗	✗
Adverts	✗	✓	✗	✗	✗	✗	✗	✗
Clear Skies notification	✓	✗	✗	✗	✗	✗	✗	✗
Celestial event notification	✓	✓[1]	✗	✗	✗	✓	✓	✗

[1] *Passes to device calendar*

Appendix G

Functional Requirements

Epic User Story				
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.				
ID	Theme	As a	I want	So that
1	GPS	User	My geographical location to be taken into account	The accuracy of the notification is maximised
2	Alert Timings	User	Sufficient preparation time to travel to a dark area	I can view the celestial event in the darkest possible sky
3	Astronomer focussed	User	The notification to be accurate and reliable	I can use it to save time and support my interest in astronomy
4	Variety	User	The notification to cover a variety of visible phenomena	I have access to a wide range of interesting celestial events
5	Event description	User	The notification badges to provide info about the celestial event	I can better understand what I am looking at if I so choose
6	Location Changer	User	A location changer	I can be informed about celestial events in an area that I am travelling to
7	How Long Visible	User	The notification badges to tell me how long the celestial event should be visible for	I can plan my time effectively
8	Event calendar	User	A monthly celestial calendar overview	I can be informed about upcoming events/ other visible objects if I so choose

9	Event image	User	The notification badges to show an image of the celestial event	I can better recognise it in the night sky
10	User Interface (UI)	User	A simple and friendly UI that requires minimum interaction	I can save time on internet research and enjoy celestial events outdoors
11	Weather	User	Reliable weather information	My outdoor viewing experiences are positive and fruitful
12	Permissions	User	To decide if the app runs on Wi-Fi, mobile data or both	I do not incur excess charges from my mobile service provider

Appendix H

Non-functional Requirements

Constraints	
Non-functional requirements	
Efficiency	Minimise internet use and access to location services
	Incidence of a celestial event should be queried when sky is dark (after sunset, before sunrise)
	Weather query instigated only if celestial event is found
	Where possible, offer user a choice about accessing the internet
	If weather conditions are found to be favourable consider other criteria that can affect visibility such as full moon.
Accurate	All celestial event and weather queries are informed by GPS
	Use effective parameters of favourable observing weather conditions
	Accurate, reliable, maintained APIs used
	Accurate correlation of celestial event and information about it
	Do not accept coordinates for outside of UK
Portable	Built for mobile
	Internet required for API queries. User informed of this requirement
	Access to device Geolocation services to determine coordinates
	User can use their current location or can input the location of their preferred observing site or local Dark Sky Site
Testable	Create artificial scenarios to check functionality before first release
	Develop regular tests to ensure that 3rd party APIs remain maintained and accurate
Maintainable/ Scalable/	Develop an architectural design that is characterised by high cohesion and low coupling

Modifiable	
	Consider a hybrid-app platform
	Develop regular tests to ensure that 3rd party APIs remain maintained and accurate
Reliable	Accurate notifications are key to the success of the project - aim is for the user to have a positive experience of outdoor viewing
Easy to operate/ minimal interaction	Simple, clean interface with minimal user input required
	Adhering where possible to the pervasive/ ubiquitous computing paradigm

Appendix I

Clear Skies Product Backlog

Release Planning

					Hours	
		From	To	Duration	Forecast	Actual
Sprint	0	21/03/2016	03/04/2016	2 weeks	80	120
	0	23/06/2016	29/06/2016	1 week	plus 40	
Sprint	1	30/06/2016	12/06/2016	2 weeks	80	72
	Prepare report	13/06/2016	19/06/2016	1 week	40	40
	Design & Implementation Report	21/06/2016				
	Refactor	22/06/2016	28/06/2016	1 week	40	40
Sprint	2	04/07/2016	17/07/2016	2 weeks	80	90
Sprint	3	18/07/2016	31/07/2016	2 weeks	80	74
Sprint	4	01/08/2016	14/08/2016	2 weeks	80	81
	Refactor and make final amends	15/08/2016	18/08/2016	4 days	32	32

		Revised
Release	01/08/2016	18/08/2016
System Testing	01/08/2016	18/08/2016
Acceptance Testing	01/08/2016	18/08/2016
Dissertation complete	19/08/2016	30/08/2016
Dissertation final submission	01/09/2016	
Dissertation complete	19/08/2016	30/08/2016
Dissertation submission	01/09/2016	31/08/2016

Testing

Unit		Ongoing	White box
Integration		Ongoing	White box
System		18/08/2016	Black box
Acceptance		18/08/2016	Black box

Priorities

HIGH	Required as part of minimum viable prototype
MED	Possible extensions
LOW	Future development

Please note

This document is updated regularly

Scoping

Core functionality as described by user cases	
Deferred user cases:	
	Learn More - Celestial Events
	Learn More - Notification
	Turn on/ off application background work

Release Schedule

Constraints

Non-functional requirements

Efficiency	Minimise internet use and access to Gelocation services
	Incidence of a celestial event should be queried when sky is dark (after sunset, before sunrise)
	Weather query instigated only if celestial event is found
	Where possible, offer user a choice about accessing the internet
	If weather conditions are found to be favourable consider other criteria that can affect visibility such as full moon.
Accurate	All celestial event and weather queries are informed by GPS
	Use effective parameters of favourable observing weather conditions
	Accurate, reliable, maintained APIs used
	Accurate correlation of celestial event and information about it
	Do not accept coordinates for outside of UK
Portable	Built for mobile
	Internet required for API queries. User informed of this requirement
	Access to device Geolocation services to determine coordinates
	User can use their current location or can input the location of their preferred observing site or local Dark Sky Site
Testable	Create artificial scenarios to check functionality before first release
	Develop regular tests to ensure that 3rd party APIs remain maintained and accurate
Maintainable/	Develop an architectural design that is characterised by high cohesion and low coupling
Scalable/	Consider a hybrid-app platform
Modifiable	Develop regular tests to ensure that 3rd party APIs remain maintained and accurate
Reliable	Accurate notifications are key to the success of the project - aim is for the user to have a positive experience of outdoor viewing
Easy to operate/	Simple, clean interface with minimal user input required
Minimal interaction	Adhering where possible to the pervasive/ ubiquitous computing paradigm
	Currently out of scope for first release

Constraints

Epic User Story
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.

ID	Theme	As a	I want	So that		Actions	Priority	VALUE	RISK	PRIORITY	NECESSITY	SUM
1	GPS	User	my geographical location to be taken into account	the accuracy of the notification is maximised	1.1	Access device GPS coordinates	HIGH	5	1	5	5	16
					1.2	Verify GPS coordinates are within scope of app (UK)	HIGH	5	1	5	5	16
2	Alert Timings	User	sufficient preparation time to travel to a dark area	I can view the celestial event in the darkest possible sky	2.1	Create user input field to allow user to define time of notification	HIGH	5	1	5	5	16
					2.2	Access local time on device	HIGH	5	0	5	5	15
					2.3	Access sunset and sunrise times based on device coordinates	HIGH	5	1	5	5	16
					2.4	Raise a notification at a specific time	HIGH	5	1	5	5	16
					2.5	Raise a notification that shows the AuroraWatch result	HIGH	5	1	5	5	16
					2.6	Raise a notification that shows the Forecast.io result	HIGH	5	1	5	5	16
					2.7	Raise a notification that shows open-notify data	HIGH	5	1	5	5	16
					2.8	Show all notification data in Main activity	HIGH	5	0	5	5	15
3	Astronomer-focussed	User	the notification to be accurate and reliable	I can use it to save time and support my interest in astronomy	3.1	Create a class that defines acceptable weather parameters for clear skies	HIGH	5	2	5	5	17
					3.2	Create a class that defines acceptable likelihood of aurora occuring given user coordinates	HIGH	5	3	5	4	17
					3.3	Create a class that defines visible ISS using user coordinates		5	3	5	4	17
4	Variety	User	the notification to cover a variety of visible phenomena	I have access to a wide range of interesting celestial events	4.1	Make calls to AuroraWatch API and parse XML	HIGH	5	1	5	5	16
					4.2	Make calls to open-notify API and parse JSON	HIGH	5	1	5	5	16
					4.3	Make calls to SkyWatch API and parse JSON	MED	5	2	3	3	13
					4.4	Make calls to N2YO API and parse (SOAP web services)	MED	5	2	3	3	13
					4.5	Implement Cloud Messaging for real-time updates	MED	4	2	3	3	12
5	Event description	User	the notification badges to provide info about the celestial event	I can better understand what I am looking at if I so choose	5.1	Select "Aurora" from menu opens webpage in app browser	MED	4	1	2	4	11
					5.2	Select "ISS" from menu opens webgae in app browser	MED	4	1	2	4	11
					5.3	Click on event in main page opens google search of event in app browser	MED	4	1	4	4	13

Epic User Story
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.

ID	Theme	As a	I want	So that		Actions	Priority	VALUE	RISK	PRIORITY	NECESSITY	SUM
6	Location Changer	User	a location changer	I can be informed about celestial events in an area that I am travelling to	6.1	Use user's roaming coordinates to make query	HIGH	5	1	5	5	16
					6.2	User inputs preferred location (text) and the coordinates are stored	MED	5	1	2	4	12
					6.2	User inputs preferred location (coords) and the coordinates are stored	MED	5	1	2	4	12
					6.3	Convert device coords into text for meaningful display	HIGH	5	1	5	5	16
7	How Long Visible	User	the notification badges to tell me how long the celestial event should be visible for	I can plan my time effectively	7.1	Display ISS passover time in main activity	HIGH	5	1	5	5	16
8	Event calendar	User	a monthly celestial calendar overview	I can be informed about upcoming events/ other visible objects if I so choose	8.1	Use predictthesky API to provide info on visible stars and planets	LOW	2	1	2	2	7
9	Event image	User	the notification badges to show an image of the celestial event	I can better recognise it in the night sky	9.1	Click on event in main page opens google search of event in app browser	LOW	3	2	2	2	9
10	User Interface (UI)	User	a simple and friendly UI that requires minimum interaction	I can save time on internet research and enjoy celestial events outdoors	10.1	Developing a user interface that requires minimum input	HIGH	5	1	5	5	16
					10.2	Develop notification to alert the user to a successful result	HIGH	5	1	5	5	16
					10.3	Accessing the Hubble Telescope Image API and returning images	LOW					
11	Weather	User	reliable weather information	My outdoor viewing experiences are positive and fruitful	11.1	Make calls to Forecast.io and parse JSON	HIGH	5	1	5	5	16
					11.2	Phases of the moon	LOW	4	1	2	2	9
12	Permissions	User	to decide if the app runs on wifi, mobile data or both	I do not incur excess charges from my mobile service provider	12.1	Request to switch to mobile data (optional for app)	LOW	2	1	2	3	8

Epic User Story
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.

ID	Theme	Actions	Priority	DETERMINING BACKLOG PRIORITY					Size	Time Estimate (hours)	Time Actual	Status
				VALUE	RISK	PRIORITY	NECESSITY	SUM				
3	Astronomer-focussed	Confirm definite astronomy and weather information sources	HIGH	5	2	5	5	17	6	n/a	n/a	n/a
4	Variety	Select astronomy events to be included based on what is available, reliable and of interest	HIGH	5	2	5	5	17	6	n/a	n/a	n/a
6	Quality	Choose and implement project management tool that recognises knowledge gained as the project progresses and facilitates adaptation of it's development, specification and outcomes	HIGH	5	0	5	5	15	6	n/a	n/a	n/a
9	Scalable	Research and develop an architectural design that encompasses characteristics of high cohesion and low coupling	HIGH	5	0	5	5	15	6	n/a	n/a	n/a
9	Scalable	Choose a suitable programming language	HIGH	5	2	5	5	17	4	n/a	n/a	n/a
8	Accessibility	Decide on suitable application development platform	HIGH	4	0	5	5	14	2	n/a	n/a	n/a
4	Variety	How do increased number of calls to API affect mobile battery?	HIGH	5	2	4	5	16	3	n/a	n/a	n/a
9	Scalable	How do increased number of calls to API affect mobile battery and data usage?	HIGH	5	3	4	5	17		n/a	n/a	n/a
7	Maintenance	Research and develop a suitable testing strategy	HIGH	4	1	4	5	14	6	n/a	n/a	n/a
5	Viewing the event	Find out what is availabe for the chosen astronomy resources and if possible define processing criteria for each category (naked eye, binoculars, telescope)	HIGH	4	2	4	5	15	6	n/a	n/a	n/a
5	Viewing the event	Consider whether or not to include only events visible with the naked eye	HIGH	4	2	4	5	15	4	n/a	n/a	n/a

Please note:

Iteration 0 is not an official sprint. It provides detail of preparatory work required before initiating sprints

Determining backlog priority: Range of 1 - 5 where 5 signifies highest possible, and 1 signifies lowest possible
Determining Size: Estimate Range of 1 - 10 where 10 signifies the most time and 1 signfies the least time. Estimates are relative to each other.

Iteration 0

Epic User Story
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.

ID	Theme		Actions	Priority	DETERMINING BACKLOG PRIORITY					Size	Time Estimate (hours)	Time Actual	Status
					VALUE	RISK	PRIORITY	NECESSITY	SUM		80		
2	Alert Timings	2.4	Raise a notification at a specific time	HIGH	5	1	5	5	16	5	14.8	8	Complete
2	Alert Timings	2.5	Raise a notification that shows the AuroraWatch result	HIGH	5	1	5	5	16	5	14.8	8	Complete
2	Alert Timings	2.6	Raise a notification that shows the Forecast.io result	HIGH	5	1	5	5	16	5	14.8	8	Complete
2	Alert Timings	2.8	Show all notification data in Main activity	HIGH	5	0	5	5	15	2	5.9	16	Complete
4	Variety	4.1	Make calls to AuroraWatch API and parse XML	HIGH	5	1	5	5	16	5	14.8	16	Complete
11	Weather	11.1	Make calls to Forecast.io and parse JSON	HIGH	5	1	5	5	16	5	14.8	16	Complete
										27	80	72	

Determining backlog priority: Range of 1 - 5 where 5 signifies highest possible, and 1 signifies lowest possible
Determining Size: Estimate Range of 1 - 10 where 10 signifies the most time and 1 signfies the least time. Estimates are relative to each other.

Iteration 1

Epic User Story
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.

ID	Theme		Actions	Priority	DETERMINING BACKLOG PRIORITY					Size	Time Estimate (hours)	Time Actual	Status
					VALUE	RISK	PRIORITY	NECESSITY	SUM		80		
1	GPS	1.1	Access device GPS coordinates	HIGH	5	1	5	5	16	2	7.0	40	Complete
		1.2	Verify GPS coordinates are within scope of app (UK)	HIGH	5	1	5	5	16	3	10.4	5	Complete
2	Alert Timings	2.7	Raise a notification that shows open-notify data	HIGH	5	1	5	5	16	2	7.0	1	Complete
3	Astronomer-focussed	3.1	Create a class that defines acceptable weather parameters for clear skies	HIGH	5	2	5	5	17	3	10.4	6	Complete
3	Astronomer-focussed	3.2	Create a class that defines acceptable likelihood of aurora occuring given user coordinates	HIGH	5	3	5	4	17	4	13.9	6	Complete
		3.3	Create a class that defines visible ISS using user coordinates		5	3	5	4	17	4	13.9	16	Complete
4	Variety	4.2	Make calls to open-notify API and parse JSON	HIGH	5	1	5	5	16	5	17.4	16	Complete
										23	80.0	90	

Determining backlog priority: Range of 1 - 5 where 5 signifies highest possible, and 1 signifies lowest possible
Determining Size: Estimate Range of 1 - 10 where 10 signifies the most time and 1 signfies the least time. Estimates are relative to each other.

Iteration 2

Epic User Story
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.

ID	Theme	Actions	Priority	DETERMINING BACKLOG PRIORITY					Size	Time Estimate (hours)	Time Actual	Status
				VALUE	RISK	PRIORITY	NECESSITY	SUM		80		
2	Alert Timings	2.1 Create user input field to allow user to define time of notification	HIGH	5	1	5	5	16	10	25.8	32	Complete
		2.2 Access local time on device	HIGH	5	0	5	5	15	2	5.2	8	Complete
		2.3 Access sunset and sunrise times based on device coordinates	HIGH	5	1	5	5	16	5	12.9	8	Complete
6	Location Changer	6.1 Use user's roaming coordinates to make query	HIGH	5	1	5	5	16	4	10.3	6	Complete
		6.3 Convert device coords into text for meaningful display	HIGH	5	1	5	5	16	4	10.3	8	Complete
7	How Long Visible	7.1 Display ISS passover time in main activity	HIGH	5	1	5	5	16	6	15.5	12	Complete
									31		74	

Determining backlog priority: Range of 1 - 5 where 5 signifies highest possible, and 1 signifies lowest possible
Determining Size: Estimate Range of 1 - 10 where 10 signifies the most time and 1 signfies the least time. Estimates are relative to each other.

Iteration 3

Epic User Story
As a user, I want to be informed about celestial events when their visibility in the highly likely, so that I can greatly improve my chance of experiencing them for myself in their natural home, the night sky.

ID	Theme	Actions	Priority	DETERMINING BACKLOG PRIORITY					Size	Time Estimate (hours)	Time Actual	Status
				VALUE	RISK	PRIORITY	NECESSITY	SUM		80		
10	User Interface (UI)	10.1 Developing a user interface that requires minimum input	HIGH	5	1	5	5	16	10	72.7	80	Complete
		10.2 Develop notification to alert the user to a successful result	HIGH	5	1	5	5	16	1	7.3	1	Complete
									11	80	81	

Determining backlog priority: Range of 1 - 5 where 5 signifies highest possible, and 1 signifies lowest possible
Determining Size: Estimate Range of 1 - 10 where 10 signifies the most time and 1 signfies the least time. Estimates are relative to each other.

Iteration 4

Appendix J

User cases (Includes normal and alternative flow of events. Excludes exceptional flow of events)

User case: Download app

App is downloaded
Pop-up dialog box displays Permissions (internet, access to device coordinates, alarm) requested for app to work
If accepted with "OK" button, app opens for the first time.
Main UI displays the app's default preferences, which are overlaid with a welcome screen.
The user taps the welcome screen, the Settings Activity opens and the user experience continues as per "Setting-up preferences"
If not accepted, user is notified that app will not work

User case: Setting-up preferences

Clicking the Overlay opens the Settings Activity

- Location preference:
  - Roaming - uses the device coordinates at the time the background work is initiated
  - Default – roaming
  - ** Currently only roaming is available **

- Event preference:
  - Aurora, ISS passover or both (check boxes) (not mutually exclusive)
  - Default - both

- Checking time:
  - User clicks this preference option
  - A dialog opens with a time picker widget that allows the user to easily select their preferred time in hours and minutes
- Hit "Save" to save time preference
- Selected time is shown on the time preference option summary
- Toast confirms the selected checking time
- If the preferred time is later than the current time
  - Background work begins at the time selected on that day
- Else
  - Background work begins at the time selected the following day

User case: Updating preferences

User opens app via app icon or notification
The main page of the app is opened
User accesses the menu bar hidden items, the "Settings" option is selected

- Location preference:
  - Existing preference shown using a radio button.
  - ** Currently only roaming is available **

- Event preference:
  - Existing preferences shown using checkboxes. Update using the checkboxes.

- Checking time:
  - User clicks this preference option
  - A dialog opens with a time picker widget that allows the user to easily select their preferred time in hours and minutes
- Hit "Save" to save time preference
- Selected time is shown on the time preference option summary
- Toast confirms the selected checking time
- If the preferred time is later than the current time
  - Background work begins at the time selected on that day
- Else
  - Background work begins at the time selected the following day

User case: View notification

App triggers alarm sound, notification appears in action bar & as dialog box when screen is locked.

- The notification displays
  - "Clear Skies!"
  - "Aurora Indicator: Yellow/ Orange/ Red"
  - "ISS overhead at XXX for XXX secs"
- as appropriate

Clicking on the notification in the action bar opens the main page of the app

- The main page of the app displays
  - Today’s date

The details of the event(s)
A breakdown of the pertinent weather conditions
The location on which the result is based
Detail of when the next query will be made

User case: View most recent information from the app

User opens the app via app icon
The main page of the app displays
Today's date
Detail of when the next query will be made

User case: Refresh the application

User opens the app via app icon
The main page of the app displays
Today's date
Detail of when the next query will be made
User selects the refresh icon from the Main Activity menu
Progress bar indicates background work is taking place
When background work is complete, UI is updated
The main page of the app displays
Today's date
The details of the event(s)
A breakdown of the pertinent weather conditions
The location on which the result is based
Detail of when the next query will be made

User case: Active UI when the Checking time is reached

The main page of the app displays
Today's date
Detail of when the next query will be made

At checking time:
- Progress bar indicates background work is taking place
  - When background work is complete, UI is updated
  - The main page of the app displays
    - Today’s date
    - The details of the event(s)
    - A breakdown of the pertinent weather conditions
    - The location on which the result is based
    - Detail of when the next query will be made

User case: Learn More - Celestial Events

User opens app via app icon
The main page of the app is opened
User accesses a sliding menu, the relevant "Aurora" or "ISS" option is selected
- Press Aurora:
  - The AuroraWatch website opens inside the app browser
  - Hit the back button on the device to return to app's sliding menu
- Press ISS:
  - The Spot The ISS website opens inside the app browser
  - Hit the back button on the device to return to app's sliding menu

User case: Learn More - Notification

User opens app via notification
- The main page of the app displays
  - Today’s date
  - The details of the event(s)
  - A breakdown of the pertinent weather conditions
  - The location on which the result is based
  - Detail of when the next query will be made

User can press the event or weather information presented
- Press Weather:
  - The Forecast.io website opens inside the app browser

Hit back to return to the app’s Main Activity
Press Aurora:
The AuroraWatch website opens inside the app browser
Hit back to return to the app’s Main Activity
Press ISS:
The Spot The ISS website opens inside the app browser
Hit back to return to the app’s Main Activity

User case: Turn on/ off application background work

User opens app via app icon or notification
The main page of the app is opened
User accesses the "Settings" option via the menu bar
Press Disable/ Enable Application radio button
Toast "Application has been disabled/ enabled"
User returns to Main Activity
UI displays "Clear Skies currently disabled"

Appendix K

United Kingdom Latitude & Longitude Map

http://www.mapsofworld.com/lat_long/united-kingdom-lat-long.html

Appendix L

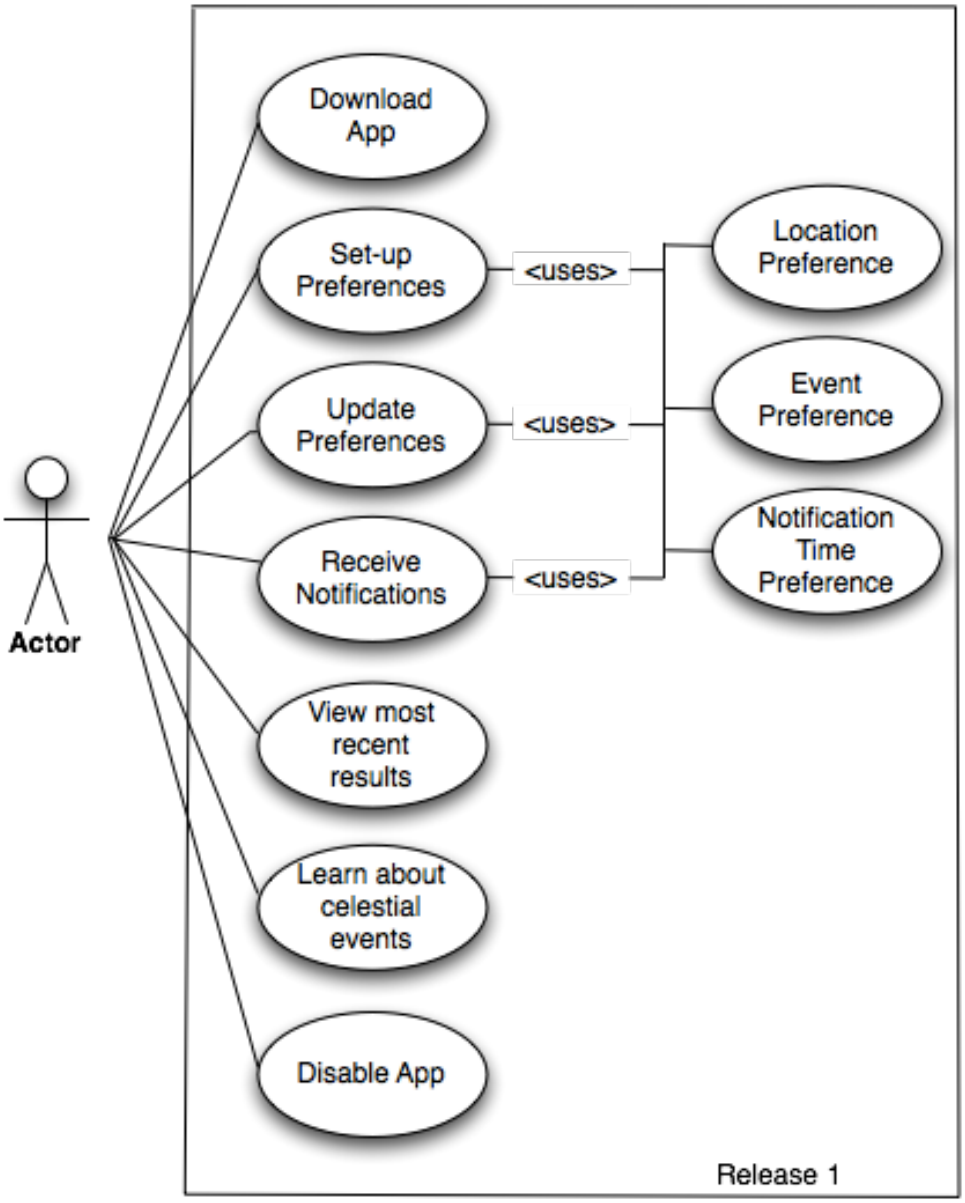
Clear Outside Astronomer Forecast: Estimated Traffic Light Bounds

Factor	Traffic Light	Bounds
Visibility (miles)	Green	9 - 10
	Amber	6 - 8
	Red	< 6
Precipitation (%)	Green	0 - 25
	Amber	26 - 50
	Red	> 51
Humidity (%)	Green	0 - 80
	Amber	81 - 90
	Red	> 91
Cloud Cover	0-1 % of sky occluded by clouds	Not included in traffic light system

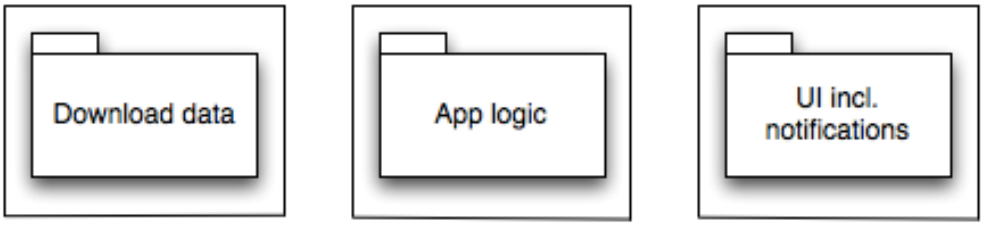
Appendix M

UML Diagrams used in the design process. Work in progress.

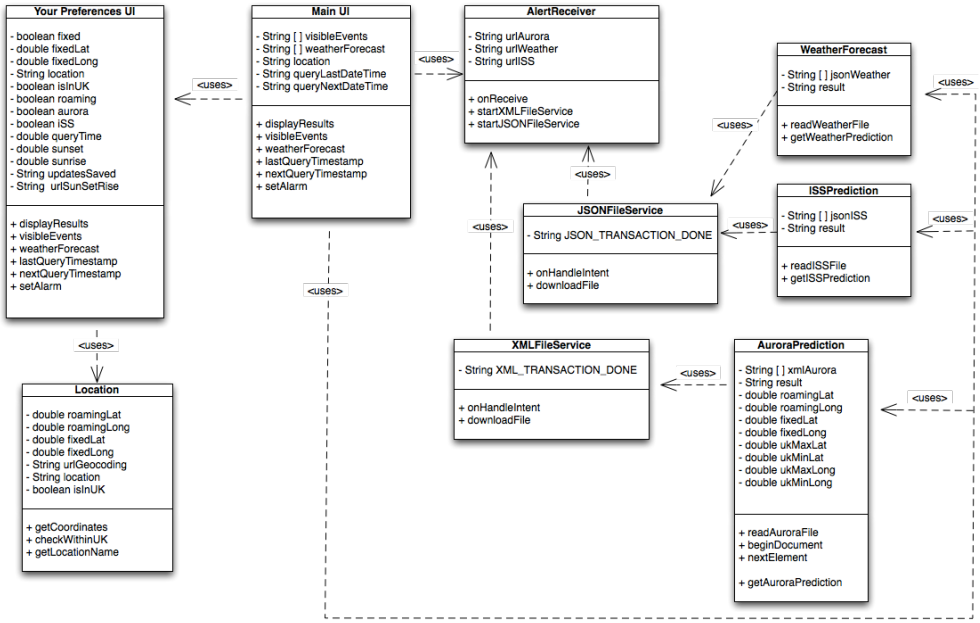
Use Case Diagram:



Package Diagram:



Class Diagram:



Appendix N

Clear Skies Testing Log

	Testing scenarios						Checked
1	open app first time	default prefs displayed on main UI screen					✓
		welcome overlay					✓
		user clicks overlay					✓
		settings open					✓
			user defines their settings				
				Checking Time			✓
				Events			✓
				Preferences			✓
					hit device back button		✓
					UI is updated		✓
					hit CS back button		✓
					UI is updated		✓
			user does not define their settings				
				hit device back button			✓
				UI shows defaults			✓
				hit CS back button			✓
				UI shows defaults			✓
2	open app	from device homescreen					
			"Next Update" info displayed in UI				✓
		from notification					
			event info displayed in UI				✓
			weather info displayed in UI				✓
			"Next Update" info displayed in UI				✓
3	settings	access settings from menu					✓
		settings open					✓
			user defines their settings				
				hit device back button			✓
				UI is updated			✓
				hit CS back button			✓
				UI is updated			✓
			user does not define their settings				
				hit device back button			✓
				UI shows defaults			✓
				hit CS back button			✓
				UI shows defaults			✓
4	settings: events	access settings from menu					
		settings open					
			select/ deselect Aurora				✓
			select/ deselect ISS				✓
5	settings: checking time	open app from device homescreen					✓
		access settings from menu					✓
		change the checking time					✓
		updates in settings summary					✓
		hit device or app back button					✓
		UI is updated with new preference					✓
		UI is updated when checking time is reached					✓
6	refresh	open app from device homescreen					✓
		access refresh from menu					✓
		UI is updated					✓
7	no internet	turn off Wi-Fi & metered data					✓
			set checking time for +2mins				✓
			UI is updated when checking time is reached				✓
			UI displays " No Network Access"				✓
				wait 2 minutes			✓
				wait 10 minutes			✓
				wait 2 hours			✓
					turn on Wi-Fi		✓
					UI is updated with result of background check		✓
					turn on metered data		✓
					UI is updated with result of background check		✓
	out of range result is dummy boolean - dummy coordinate data not supplied						
8	out of range	access main UI					✓
		UI displays "Out of Range"					✓
		UI displays "Next Update"					✓
	data success results for dummy boolean - dummy file data is not supplied and parsed						
9	background work	location					
			success				
				weather			
					success		
						ISS success, ISS not selected	UI displays "Nothing to Declare" ✓
							UI displays "Next Update" ✓
						Aurora success, Aurora not selected	UI displays "Nothing to Declare" ✓
							UI displays "Next Update" ✓

						ISS & Aurora success, neither selected	UI displays "Nothing to Declare"	✓
							UI displays "Next Update"	✓
						ISS success, ISS selected	UI displays ISS event	✓
							UI displays weather info	✓
							UI displays next update info	✓
							Alert notification is raised	✓
						Aurora success, aurora selected	UI displays Aurora event	✓
							UI displays weather info	✓
							UI displays next update info	✓
							Alert notification is raised	✓
						ISS & Aurora success, both selected	UI displays both events	✓
							UI displays weather info	✓
							UI displays next update info	✓
							Alert notification is raised	✓
						ISS failure, ISS not selected	UI displays "Nothing to Declare" & "Next Update"	✓
						Aurora failure, Aurora not selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS & Aurora failure, neither selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS failure, ISS selected	UI displays "Nothing to Declare" & "Next Update"	✓
						Aurora failure, aurora selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS & Aurora failure, both selected	UI displays "Nothing to Declare" & "Next Update"	✓
					failure			
						ISS success, ISS not selected	UI displays "Nothing to Declare" & "Next Update"	✓
						Aurora success, Aurora not selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS & Aurora success, neither selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS success, ISS selected	UI displays "Nothing to Declare" & "Next Update"	✓
						Aurora success, aurora selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS & Aurora success, both selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS failure, ISS not selected	UI displays "Nothing to Declare" & "Next Update"	✓
						Aurora failure, Aurora not selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS & Aurora failure, neither selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS failure, ISS selected	UI displays "Nothing to Declare" & "Next Update"	✓
						Aurora failure, aurora selected	UI displays "Nothing to Declare" & "Next Update"	✓
						ISS & Aurora failure, both selected	UI displays "Nothing to Declare" & "Next Update"	✓
			failure					
				out of range				
					UI displays "Out of Range"			✓
				unable to lock coordinates				
					Currently not dealt with			
	weather tier dummy data uses 0 or 1, dummy data not supplied to file and parsed							
10	weather	success						
			weather tier 0: green					
			event success					✓
			sunset time correct					✓
			sunrise time correct					✓
			displayed in UI in correct format					✓
			displayed in notification					✓
			weather tier 1: amber					
			event success					✓
			sunset time correct					✓
			sunrise time correct					✓
			displayed in UI in correct format					✓
			displayed in notification					✓
11	next update	main UI	correct checking time					✓
			correct use of "Today", "Tomorrow"					✓
			correct ListView format					✓
12	result notification	main UI	ISS event					
				current location displayed				✓
				time of passover displayed				✓
				correct ListView format				✓
			Aurora event					
				current location displayed				✓
				likelihood of aurora displayed				✓
				correct ListView format				✓
			ISS & Aurora event					
				both displayed in correct ListView format				✓
13	notification	accessed in the notification bar						
			Aurora success displayed correctly					✓
			ISS success displayed correctly					✓
			Aurora, ISS success displayed correctly					✓
					weather tier 0: green			✓
					weather tier 1: amber			✓
						click notification		✓
						opens corresponding UI in the application		✓
14	friendly date	main UI	each time main UI is accessed					
				correct date				✓
				correct date format				✓
15	no notification permission							
		main UI						
		currently not dealt with						
16	reboot device							
		main UI						
		updates at checking time						✓

Appendix O

Clear Skies Prototype Testing: Focus Group Questionnaire and Results

Clear Skies Questionnaire

User Feedback

1. **About You - Please select the option that best applies to you**
   Mark only one oval.
   - ( ) I am not interested in astronomy
   - ( ) I am interested in astronomy but have not pursued it
   - ( ) I am a beginner observer
   - ( ) I am an intermediate observer
   - ( ) I am a experienced observer
   - ( ) I am an astronomy professional

2. **What version of the Android OS are you using? (Usually found in Settings under About Device)**

   _____

3. **What mobile device are you using (e.g. Samsung Galaxy S III)**

   _____

4. **Downloading and using the app - please check the boxes that apply**
   Check all that apply.
   - [ ] Successful: Download
   - [ ] Successful: Welcome screen displays and leads to user settings
   - [ ] Successful: Manipulation of user settings
   - [ ] Successful: Main homepage of app updates based on your preferred "checking time"
   - [ ] Successful: Main homepage of app updates based on the refresh button being used

5. **User Interface - Please check the boxes that apply**
   Check all that apply.
   - [ ] Screen displays Welcome with defaults
   - [ ] Screen displays Next Update with applicable checking time
   - [ ] Screen displays result of check: Nothing to Declare
   - [ ] Screen displays result of check: Success (e.g. ISS passover)

6. **Notifications - Please check the boxes that apply**
   Check all that apply.
   - [ ] The app raised a notification
   - [ ] The notification made a sound
   - [ ] The notification vibrated the device
   - [ ] The notification alerted you to the Aurora
   - [ ] The notification alerted you to an ISS passover
   - [ ] The notification alerted you to both the aurora and an ISS passover (Ker-ching!)

7. **Is it easy to navigate the application?**
   Mark only one oval.

	1	2	3	4	5	
Not easy	( )	( )	( )	( )	( )	Very easy

8. **Is the design of the application attractive?**
   Mark only one oval.

	1	2	3	4	5	
Not attractive	( )	( )	( )	( )	( )	Very attractive

9. **Did the app impact on the battery life of your device?**
   Mark only one oval.

	1	2	3	4	5	
Not at all	( )	( )	( )	( )	( )	Significantly

10. **How likely are you to recommend the app to others?**
    Mark only one oval.

	1	2	3	4	5	
Not likely	( )	( )	( )	( )	( )	Very likely

11. **How long did you use the application for?**

    _____

12. **How do you like the limited interaction required for the app?**
Mark only one oval.

	1	2	3	4	5	
Would prefer something more interactive	◯	◯	◯	◯	◯	Like it

13. **What other celestial events would you like the app to provide? Select all that apply**
Mark only one oval.

- ◯ Planets
- ◯ Moon
- ◯ Stars and Constellations
- ◯ Comets
- ◯ Asteroids
- ◯ Meteors
- ◯ Messier Objects
- ◯ Deep Sky
- ◯ Other satellites
- ◯ ALL OF THE ABOVE

14. **Did the app display unusual behaviour while you were using it? Please describe.**

15. **Do you have any additional comments/ suggestions?**

Future Development

How would you rate the importance of the following features for future development of the app?
Please number from 1 (most important) to 8 (least important)

16. **Checking time range (e.g. 21:00 - 04:00) instead of one specific checking time**

17. **Explicit button in the settings to turn off (and back on) the daily background check**

18. **Option to input your own location preference**

19. **Extend the app to work outside of the UK**

20. **Include more detail about the events themselves**

21. **Include more detail about how to find the events in the sky**

22. **Include a breakdown of the weather forecast if a notification is raised**

23. **Widen the range of celestial events covered by the app**

anne.mcauley@gmail.com

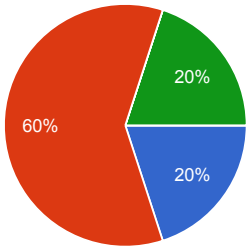
Edit this form

5 responses

View all responses

Summary

About You - Please select the option that best applies to you



I am not interested in astronomy	1	20%
I am interested in astronomy but have not pursued it	3	60%
I am a beginner observer	0	0%
I am an intermediate observer	1	20%
I am a experienced observer	0	0%
I am an astronomy professional	0	0%
I am not interested in astronomy	1	20%
I am interested in astronomy but have not pursued it	3	60%
I am a beginner observer	0	0%
I am an intermediate observer	1	20%
I am a experienced observer	0	0%
I am an astronomy professional	0	0%

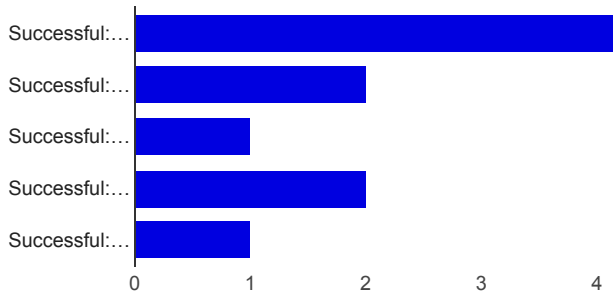
What version of the Android OS are you using? (Usually found in Settings under About Device)

6.0
Ice cream sandwich
Android 6 Marshmallow
5.0.2
6.0
Ice cream sandwich
Android 6 Marshmallow
5.0.2

What mobile device are you using (e.g. Samsung Galaxy S III)

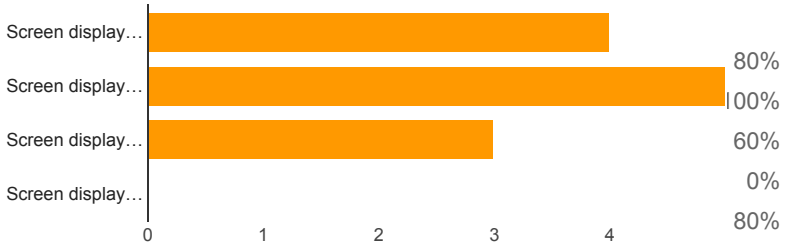
S7 edge
Galaxy tab 10.1n
Samsung 6
Samsung Galaxy S5
S7 edge
Galaxy tab 10.1n
Samsung 6
Samsung Galaxy S5

Downloading and using the app - please check the boxes that apply



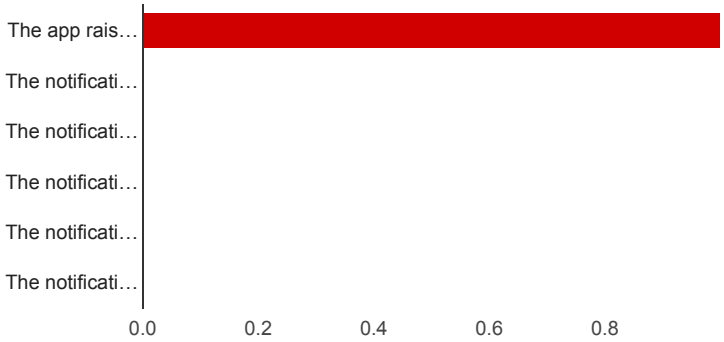
Successful: Download	**5**	100%
Successful: Welcome screen displays and leads to user settings	**2**	40%
Successful: Manipulation of user settings	**1**	20%
Successful: Main homepage of app updates based on your preferred "checking time"	**2**	40%
Successful: Main homepage of app updates based on the refresh button being used	**1**	20%
Successful: Download	**5**	100%
Successful: Welcome screen displays and leads to user settings	**2**	40%
Successful: Manipulation of user settings	**1**	20%
Successful: Main homepage of app updates based on your preferred "checking time"	**2**	40%
Successful: Main homepage of app updates based on the refresh button being used	**1**	20%

User Interface - Please check the boxes that apply



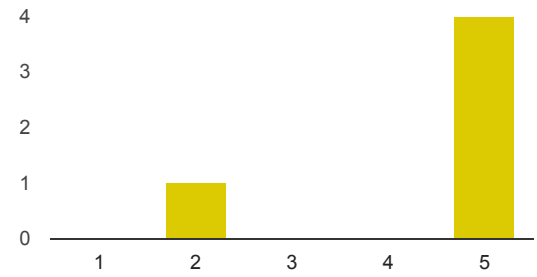
		80%
		100%
		60%
		0%
		80%
Screen displays Next Update with applicable checking time	**5**	100%
Screen displays result of check: Nothing to Declare	**3**	60%
Screen displays result of check: Success (e.g. ISS passover)	**0**	0%

Notifications - Please check the boxes that apply



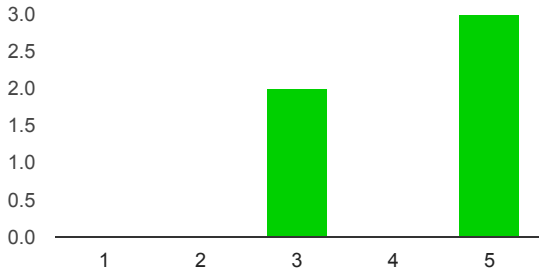
The app raised a notification	**1**	100%
The notification made a sound	**0**	0%
The notification vibrated the device	**0**	0%
The notification alerted you to the Aurora	**0**	0%
The notification alerted you to an ISS passover	**0**	0%
The notification alerted you to both the aurora and an ISS passover (Ker-ching!)	**0**	0%
The app raised a notification	**1**	100%
The notification made a sound	**0**	0%
The notification vibrated the device	**0**	0%
The notification alerted you to the Aurora	**0**	0%
The notification alerted you to an ISS passover	**0**	0%
The notification alerted you to both the aurora and an ISS passover (Ker-ching!)	**0**	0%

Is it easy to navigate the application?



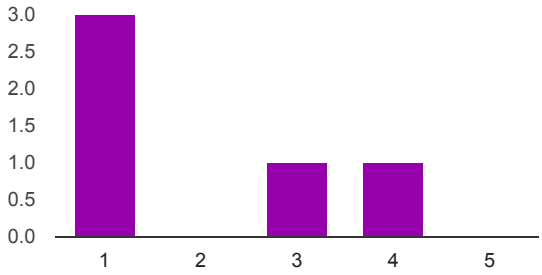
3	**0**	0%
4	**0**	0%
Very easy: 5	**4**	80%
Not easy: 1	**0**	0%
2	**1**	20%
3	**0**	0%
4	**0**	0%
Very easy: 5	**4**	80%

Is the design of the application attractive?



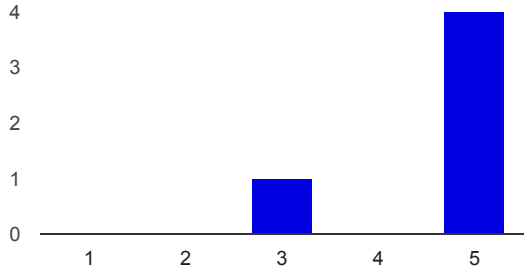
Not attractive: 1	**0**	0%
2	**0**	0%
3	**2**	40%
4	**0**	0%
Very attractive: 5	**3**	60%
Not attractive: 1	**0**	0%
2	**0**	0%
3	**2**	40%
4	**0**	0%
Very attractive: 5	**3**	60%

Did the app impact on the battery life of your device?



Not at all: 1	**3**	60%
2	**0**	0%
3	**1**	20%
4	**1**	20%
Significantly: 5	**0**	0%
Not at all: 1	**3**	60%
2	**0**	0%
3	**1**	20%
4	**1**	20%
Significantly: 5	**0**	0%

How likely are you to recommend the app to others?

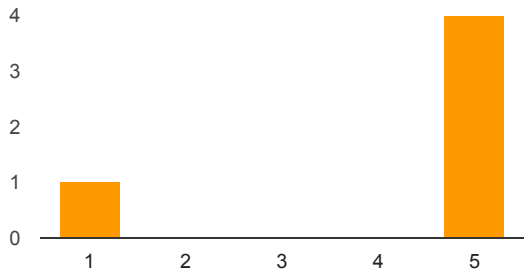


Not likely: 1	**0**	0%
2	**0**	0%
3	**1**	20%
4	**0**	0%
Very likely: 5	**4**	80%
Not likely: 1	**0**	0%
2	**0**	0%
3	**1**	20%
4	**0**	0%
Very likely: 5	**4**	80%

How long did you use the application for?

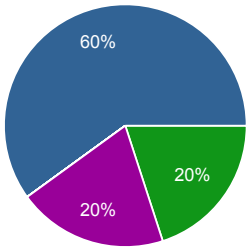
3 minutes
A week
1 day
A few hours in the evening
on going, 1st downloaded 1 week ago
3 minutes
A week
1 day
A few hours in the evening
on going, 1st downloaded 1 week ago

How do you like the limited interaction required for the app?



Would prefer something more interactive: 1	**1**	20%
2	**0**	0%
3	**0**	0%
4	**0**	0%
Like it: 5	**4**	80%
Would prefer something more interactive: 1	**1**	20%
2	**0**	0%
3	**0**	0%
4	**0**	0%
Like it: 5	**4**	80%

What other celestial events would you like the app to provide? Select all that apply



Moon	0	0%
Stars and Constellations	0	0%
Comets	1	20%
Asteroids	1	20%
Meteors	0	0%
Messier Objects	0	0%
Deep Sky	0	0%
Other satellites	0	0%
ALL OF THE ABOVE	3	60%
Planets	0	0%
Moon	0	0%
Stars and Constellations	0	0%
Comets	1	20%
Asteroids	1	20%
Meteors	0	0%
Messier Objects	0	0%
Deep Sky	0	0%
Other satellites	0	0%
ALL OF THE ABOVE	3	60%

Did the app display unusual behaviour while you were using it? Please describe.

No
Yes - kept crashing (sorry anne)
None
No
Yes - kept crashing (sorry anne)
None

Do you have any additional comments/ suggestions?

Seems great. Would including the phase of the moon in the notification also be useful. This may indicate how easy it will be to see certain things - i.e. the full moon can be quite bright. Does relying on wifi alone for your location limit its application a little? E.g. If you were on a campling holiday you might have the perfect conditions including 'proper darkness' but not get a notification.

Just that it kept crashing so i never really experienced the functionality
The welcome should be white. Overall it looks great but a little dark for me. Screen text is good as I don't need glasses to read it.
Seems great. Would including the phase of the moon in the notification also be useful. This may indicate how easy it will be to see certain things - i.e. the full moon can be quite bright. Does relying on wifi alone for your location limit its application a little? E.g. If you were on a campling holiday you might have the perfect conditions including 'proper darkness' but not get a notification.
Just that it kept crashing so i never really experienced the functionality
The welcome should be white. Overall it looks great but a little dark for me. Screen text is good as I don't need glasses to read it.

Future Development

Checking time range (e.g. 21:00 - 04:00) instead of one specific checking time

1
2
5
1
2
5

Explicit button in the settings to turn off (and back on) the daily background check

1
5
7
6
1
5
7
6

Option to input your own location preference

1
2
7
1

1
2
7
1

Extend the app to work outside of the UK

1
7
1
7

Include more detail about the events themselves

1
3
2
1
3
2

Include more detail about how to find the events in the sky

1
4
3
1
4
3

Include a breakdown of the weather forecast if a notification is raised

4
3
2
4
3
2

Widen the range of celestial events covered by the app

4

1
3
4
1
3

About You - Please select the option that best applies to you

What version of the Android OS are you using? (Usually found in Settings under About Device)

What mobile device are you using (e.g. Samsung Galaxy S III)

Downloading and using the app - please check the boxes that apply

User Interface - Please check the boxes that apply

Notifications - Please check the boxes that apply

Is it easy to navigate the application?

Is the design of the application attractive?

Did the app impact on the battery life of your device?

How likely are you to recommend the app to others?

How long did you use the application for?

How do you like the limited interaction required for the app?

What other celestial events would you like the app to provide? Select all that apply

Did the app display unusual behaviour while you were using it? Please describe.

Do you have any additional comments/ suggestions?

Future Development

Checking time range (e.g. 21:00 - 04:00) instead of one specific checking time

Explicit button in the settings to turn off (and back on) the daily background check

Option to input your own location preference

Extend the app to work outside of the UK

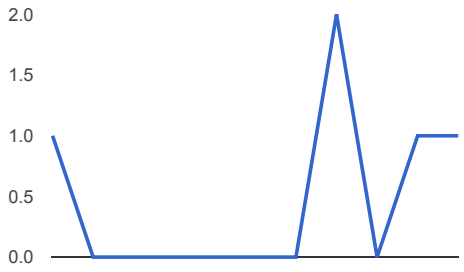
Include more detail about the events themselves

Include more detail about how to find the events in the sky

Include a breakdown of the weather forecast if a notification is raised

Widen the range of celestial events covered by the app

Number of daily responses



Number of daily responses

View all responses

Summary