

# 2021/22 candidate record form, production log and assessment record

## Level 3 Extended Project (7993)

Please attach the form to your candidate's work and keep it at the centre or send it to the moderator as required. The declarations should be completed as indicated.

Centre number

26202

Centre name

Bourne Grammar School

Candidate number

[Click here to enter.](#)

Candidate's full name

Dhruva Teja Turaga

Work submitted for assessment **must** be the candidate's own. If candidates copy work, allow candidates to copy from them, or cheat in any other way, they may be disqualified.

### Candidate declaration

Have you received help/information from anyone **other than** subject teacher(s) to produce this work?

☐ No

☐ Yes (give details below or on a separate sheet if necessary).

[Click here to enter text.](#)

Please list below any books, leaflets or other materials (for example DVDs, software packages, internet information) used to complete this work **not** acknowledged in the work itself. Presenting materials copied from other sources **without acknowledgement** is regarded as deliberate deception.

[Click here to enter text.](#)

We may use examples of candidate's work for standardisation or training purposes. Please see our privacy notice for more information on how we use assessment data and on your rights under data privacy legislation.

I have read and understood the above. I confirm I produced the attached work without assistance other than that which is acceptable under the scheme of assessment.

Candidate signature.

Date [Click here to enter a date.](#)

### Supervisor declaration

I confirm the candidate's work was conducted under the conditions laid out by the specification. I have authenticated the candidate's work and am satisfied, (to the best of my knowledge) that the work produced is solely that of the candidate.

Supervisor signature.

Date [Click here to enter a date.](#)

Candidate number

Candidate's full name

Dhruva Teja Turaga

## Submission checklist

### To be completed by the supervisor

Extended Project **working** title [Click here to enter text.](#)

Extended Project **final** title [Click here to enter text.](#)

Form of project

☐ Either written report

☐ Or [Click here to enter text.](#) and accompanying written report

Is this project part of a group project?

☐ No

☐ Yes If 'Yes', give brief details [Click here to enter text.](#)

**Please note** that failure to complete or submit a compulsory element may result in a mark of zero being awarded.

Select/tick	Items that <b>must</b> be included	Notes
<input type="checkbox"/>	1. A signed and completed <i>Candidate record form, production log and assessment record</i>	This document. All pages must be completed.
<input type="checkbox"/>	2. Research based written report	If the project product is an artefact or a production, an accompanying research based written report is also required.
<input type="checkbox"/>	3. Evidence of the project product	Eg photographs of artefact, investigation or production; a piece of creative writing (artefact); research based written report.
<input type="checkbox"/>	4. Evidence of a presentation within the production log	Presentation on the project process. Where the project product is itself a presentation (for a specified audience), a presentation on the project process must also be delivered to a non-specialist audience

**Candidate number**

**Candidate's full name**

Dhruva Teja Turaga

## The taught skills element

**To be completed by the supervisor**

### **Outline details of taught skills**

Record here details of relevant skills taught in a class/group and details of relevant skills taught individually to this candidate as described in the specification. Continue on a separate sheet if necessary.

[Click here to enter text.](#)

Candidate number

Candidate's full name

Dhruva Teja Turaga

## Record of marks

### To be completed by the supervisor

Marks must be awarded in accordance with the instructions and criteria in the specification.

Summary information to show how the marks have been awarded should be given in the spaces below in addition to comments in other pages of this document and any supporting information in the form of annotations on the candidate's work.

Skill area	Maximum mark	Mark awarded	Supervisor's supporting statement
A01 Manage	10	Click.	Click here to enter text.
A02 Use resources	10	Click.	Click here to enter text.
A03 Develop and realise	20	Click.	Click here to enter text.
A04 Review	10	Click.	Click here to enter text.
Total mark	50	Click.	

### Supervisor's concluding comments

Click here to enter text.

### Internal moderation comments if appropriate

Click here to enter text.

### Supervisor declaration

I confirm that no work assessed for the award of the marks above is also to be submitted, or has been submitted, for any other accredited qualification(s).

Supervisor signature.

Date

Click here to enter a date.

## Record of initial ideas

### To be completed by the candidate

This page records initial meeting(s) with your supervisor to agree your project ideas. Additional pages can be submitted if more than one idea has been explored.

My idea(s) for topic/title

#### **How far can humans realistically explore space right now?**

Build a new weather station which accurately plots data for the user to predict future trends based on previously known data.

Is time an illusion?

Cleaning Space Junk ideas methods, designs, and application <-potential for barrier in q1

Which new emerging technologies have the capability to end humanity and propel us to a better tomorrow.

How mathematical and physics concepts change the field of engineering.

What are the physical barriers of humanity? <-human limitations included.

My ideas for research and development of my project

After completing "A Brief history of Time" by Stephen Hawking questions began to arise as to how we could develop technologies to explore the depths of space and I decided to focus my research project on the way humans could potentially divide the gap between the Earth and Space and make it much more feasible to understand these mysteries of the universe. This led me to deliberate many ideas revolving around the issues as well as developments of space travel and why it was an important step towards increasing our knowledge of the vast endlessness and mysterious aspect of space.

Some points and subbranches of the main question which can be discussed and evaluated on could include:

Historical research on features of spacecraft and how they originally developed the main parts of the aircraft like propulsion, navigation and how we are incorporating them right now to flights to the ISS and probes to other distant planets like Mars and how they are communicating back through long distances. As well as a brief outline of how far humanity has progressed from their initial creation of technology and rate at which it is advancing and how far into the future we are expecting and to what limits can humans strive towards. However, this involves lots of research from many different fields which are not interlinked so it is too big to expand upon and there isn't a set distance to go back upon as *homo sapiens* have been fascinated by space for such a large breath to time trying to explain its how we got to certain conclusions based on evidence and experiments cannot be found like the first ancestors of humanity.

Importance of specifically space travel in general and what factors on Earth drive this as well as answering the crucial question if we are alone in the universe and explore the unknown as humans are explorers by nature and the vastness of space gives us an infinite sandbox to try many concepts and experiments again and again without catastrophic consequences. Nevertheless, retrieving primary data from this source is close to impossible without experimenting on Earth and Space to get an overview or talking to astronauts as interview sources who conducted such experiments in space.

Means of transportation including rockets with specific coolants or other unique methods such as a lift and Space Hotels, as well as the potential possibility of warp travel and how much more reliable and feasible they are in the near or distant future with the advancement of technology. But this delves into mathematical, and physics-related aspects which are much too complicated and almost in the realm of science fiction, so retrieval of data is close to zero and with the vast number of mathematical constants to take into consideration they can only be described on a theoretical level which makes this hard to discuss in the limited word count.

The design of the Aircraft and how designs now could be improved to have much more functionality and isolate on different parts of the rocket (from NASA the key parts are the structural system, the payload system, the guidance system, and the propulsion system) – for example the propulsion system contains different types of

main and alternate propulsion so if you use a nuclear pulse propulsion for the main and a magnetic sail for the alternative you can reach very high distances with maximum fuel efficiency but it takes a very long time to travel a certain distance in space and needs to be constantly adjusted which uses more energy decreasing the maximum velocity it can reach so it takes longer making this method impractical. Apart from this you could also talk about the landing problem where using new rockets every trip can be a massive waste of resources so landing the rocket can save vital technology and minerals and recycle their uses. Although this can be easy to experiment you would have to recreate models of existing rockets from scratch as well as adding in your own designs, although this could take a significantly long time to create and involves many electronic components which costs a large amount to design and manufacture especially bespoke components if you want them to do a specific task.

Problems with space travel including unknown events like asteroids, gravitational pulls of other stars and planets as well as lots of space debris floating around the earth from commissioned satellites which now have no purpose, which brings into topics such as cleaning space junk. Another point which is included in this is the reliability and communication of this spacecraft back to Earth and its prolonging time increase as it gets further away. Apart from this there are lots of unknown factors which can occur due to the unpredictability of space, so I could create simple models to experiment but there are too many control variables, so the investigative side of this will consume a large length of time.

GPS System for navigation in space is very hard to invent because you need to account for where the signals are going and where you are in comparison to the Earth in a 3D space which has lots of variables to account for which means you need a powerful computer to process them and makes it much harder to operate and requires a very large amount of memory. Although not hard to create in the near future by the rate of technological development, will be a very time-consuming process to implement. A way it could be created is by instantiating many super classes and subclasses and hundreds of methods so that each variable can be changed accordingly based on separate factors, and as a result the process would be a very time-consuming process.

Biological dilemmas such as space radiation in long distance trips there are harmful effects of cancer which aside from that it could also cause cataracts and even Alzheimer's especially when re-entering the atmosphere. As well as this you would also need a self-sufficient food source and animals in space are a massive problem because they need much longer to adapt to the weightlessness environment. Finally, the largest constraint for humans is the life limitation gap – humans only live for a finite and very short amount of time and with that time with technology today we cannot even get to Mars without using half the average human lifespan, so we would require a cryogenic chamber until we get to a destination. This topic isn't hard to discuss but very far outside my comfort zone as new biological factors are found every day and this would mean I would have to stay up to date with all the news as any of it could be revolutionary to the exploration of space. I would also have to buy fish, which are high maintenance, as that is an interesting investigation to pursue to create a self-sustaining ecosystem with plants. This would then mean harvesting the waste which will be incredibly messy and taking data would have to go on for a very long time as you would have to use the excrement as fertiliser to grow the plants.

Chemical advantages and disadvantages on efficient coolants need to be created to travel to distant galaxies as non-renewable crude oils are finite so we also need a way of refining molecules which can replenish and be not a burden or too dangerous to carry, including hydrogen fuel sources. This would mean I need to get hold of crude oils which are dead plankton under kilopascals of pressure, which are becoming scarce by the day so it would be impractical and very expensive to go for this idea to investigate.

Methods on how we can solve limitations such as create an interplanetary colonisation and its implications and the meeting of an alien race which could potentially help us overcome this issue as well. This goes into many parts of science fiction so investigating this material could be revolutionary but as a practical aspect it will never be possible or at least not for hundreds of years to come with the rate of advancement of technology.

Factor all the information and create a design of an aircraft with different technologies as well as a basis of ideas on how we can most efficiently manage time away from the Earth and manage these resources. But this is hard to make in CAD due to the number of refinements you would have to make, it is hard to manage, and changing one aspect could make the whole design effective internally but sending it to space would be impossible, especially if it were to be in space for a large length of time.

Finally, what technologies can be in place in the very distant future which can make travelling much simpler like warp speed travel or the discovery/creation of wormholes which curves the path of space time making it much easier to travel, or a perpetual motion machine (although currently impossible, this could solve the energy crisis and could bring infinite travel in space) to have an infinite or close to infinite energy source. Although this would be easy to write about in terms of experimental details it is very slim and quite a theoretical topic which scientists have been trying to investigate so the type of sources available will be scarce and limited so hard to implement effectively in an EPQ.

#### My summary of the comments and advice from my supervisor

During the beginning of the discussion, we looked at how far humans can realistically explore space. Although a very big topic when looking at it face down it was suggested that my topic included lots of aspects of technology which can be very easily investigated on a small scale and then applied on a much larger scale – this could apply to CAD designs of rockets and use a 3D printer to print the design and put the several designs in front of a fan as a wind tunnel – but however this could only apply to the exit from Earth's atmosphere because most known planets don't have a thick atmosphere to provide resistance which obviously can't apply to space – most energy released by propulsion is done within the Earth's atmosphere.

After having looked into this idea further subsequent to our discussion, I shared another idea on much more effective use of my CAD knowledge - the designs specifically of different rovers, aircrafts, orbiters and what makes them vulnerable to various space effects and makes them live exceptionally longer to give much more purpose to them – this then could link with an investigation where I could test the reliability of materials with certain densities from heights to test impact resistance from landing.

Additionally, my supervisor advised I investigate various energy production methods, which can be very useful in very long-distance exploration to creating a self-sustaining ecosystem in shuttles and crafts so humans on them don't rely so heavily on these fuels as we would in Earth. I also thought about a constant energy source which produces enough force to keep going at a constant velocity and accelerate in certain points within its journey – this is an idea for experimental primary sources of data. This is a viable topic which I could investigate and there are many secondary sources I could retrieve this from including nasa.gov and esa.int but I didn't think this was a practical design aspect as some energy generation methods could be explored but not enough to make a concrete solution to a problem.

Finally, I decided to mind map all my ideas to create a comprehensive overview of all the advice given and started linking parts which really brought to my attention as well as being detailed enough for an in-depth search and investigation as well as my own instead of just using secondary sources.

#### Modifications I have made as a result of my discussion with my supervisor

After considering all the feedback from my supervisor, I have modified my project question to "How is technology helping us find Earth 2.0?" since it reinforces all the feedback, I received from my supervisor to choose a viable topic which has enough investigable material where I can collect concrete primary data which I can use along with potential interviews to form a conclusive answer to the question. Investigations that could help me in this project include using a telescope to find out more about the night sky, using all the relevant material to pinpoint exact positions of stars and constellations, as well as testing physics concepts which could play a part in navigating the cosmos, like centripetal force from other planets which removes the need for extra propulsion.

Furthermore, it doesn't stray far from my original question but a sub-branch within it. This would mean I can still reference and talk about the importance of space travel as well as transportation but also contrast with people's views on whether we should spend money on space rather than making Earth a better place, which provides different viewpoints of looking at the same topic. This approach can show linking of ideas as well as demonstrating a critical thinking approach to the question and problem-solving capabilities.

**Candidate number**

\_\_\_\_\_

**Candidate's full name**

Dhruva Teja Turaga

\_\_\_\_\_

Date

01 February 2022

\_\_\_\_\_



## Part A: Candidate proposal

### To be completed by the candidate

Working title of my Extended Project.

Present the topic to be researched in the form of a short statement/question/hypothesis with clear focus.

How is technology helping us to locate Earth 2.0?

- my initial resources will be

I intend to use my initial resources to, firstly, assess why humanity first looked up to the stars and how we quantified space for the future of navigating with the stars and to the stars. To do this, I will have to use secondary sources like journals and scientific articles because I will not have the contacts to achieve this or accurate readable material to analyse how humanity first got into the interest of space. In the beginning I intend to use the journal article 'The History of Ancient Astronomy' by Neugebauer, which explains in detail the use for the stars which I can discuss the Egyptians, ancient Mesopotamians like the Babylonians and Mayans and then to the Hellenistic period with the development of modern mathematics from the Greeks and different cultures like Hindu Astronomy.<sup>1</sup> Then I will use the journal article 'Distance and Discrete Space' by McDaniel because a universal counting system for space is quantified very differently due to the curvature of Earth and space so can't be modelled like Earth as 3D-spaces requires 3D coordinate system.<sup>2</sup>

Subsequently, I will use the article 'Beyond Galileo's Universe' by Ron Cowen because the search started during the time of Copernicus and Galileo and the invention of the telescope to see natural satellites of Jupiter, this can then be used to question the importance for this search as astronomy was not about what can be seen but what you cannot see.<sup>3</sup> Concluding this point, I will use 'Searching for Other Earths' from Sara Seager, which shows new Earths are also within the moons of planets in our solar system.<sup>4</sup>

This although is very different for habitable exoplanets outside our solar system, so I intend to use a journal article called 'Better than Earth' by René Heller to talk about carboniferous planets<sup>5</sup> and this data can be taken from historic paintings as a secondary source could also depict extreme climate in the past of Earth to set a null hypothesis. Then I intend to use an archive by NASA which hold exoplanet data where I can use the data to compare sources making it stronger and it can be very useful to deduce how this information could be gathered from different sensors and how they could be used together to convey different messages.<sup>6</sup>

Later I plan to analyse the technologies in specific ways this includes Refractor Telescopes, Newtonian and Keplerian, but in such a way that I will talk about specific chambers common to the telescopes and what that means for the output which can be taken from a journal article called 'A New Global Array of Optical Telescopes' by Francis K Chun.<sup>7</sup> Many sensors also come into play and these uncertainties can be measured

<sup>1</sup> Neugebauer, O. "THE HISTORY OF ANCIENT ASTRONOMY: PROBLEMS AND METHODS." Publications of the Astronomical Society of the Pacific, vol. 58, no. 340, [University of Chicago Press, Astronomical Society of the Pacific], 1946, pp. 17–43, <http://www.jstor.org/stable/40671862>.

<sup>2</sup> McDaniel, K. "Distance and Discrete Space." Synthese, vol. 155, no. 1, Springer, 2007, pp. 157–62, <http://www.jstor.org/stable/27653481>.

<sup>3</sup> Cowen, Ron. "Beyond Galileo's Universe." Science News, vol. 175, no. 11, Society for Science & the Public, 2009, pp. 22–28, <http://www.jstor.org/stable/20494780>.

<sup>4</sup> Seager, Sara. "Searching for Other Earths." The New Atlantis, no. 47, Center for the Study of Technology and Society, 2015, pp. 67–75, <http://www.jstor.org/stable/43671541>.

<sup>5</sup> Heller, René. "BETTER THAN EARTH." Scientific American, vol. 312, no. 1, Scientific American, a division of Nature America, Inc., 2015, pp. 32–39, <https://www.jstor.org/stable/26046063>.

<sup>6</sup> Akeson, R. L., et al. "The NASA Exoplanet Archive: Data and Tools for Exoplanet Research." Publications of the Astronomical Society of the Pacific, vol. 125, no. 930, [The University of Chicago Press, Astronomical Society of the Pacific], 2013, pp. 989–99, <https://doi.org/10.1086/672273>.

<sup>7</sup> Chun, Francis K., et al. "A New Global Array of Optical Telescopes: The Falcon Telescope Network." Publications of the Astronomical Society of the Pacific, vol. 130, no. 991, [IOP Publishing Limited, Astronomical Society of the Pacific], 2018, pp. 1–20, <https://www.jstor.org/stable/26660659>.

and analysed with respect to their advantages and disadvantages to find purpose so I can use the journal article 'Electro-optical telescope produces first images of distant nebula' by Gigi Whitley.<sup>8</sup> Then, I will also investigate the changing of these parameters from a first-hand perspective as a primary source of data to see the difference in visibility of celestial objects from my own personal refractor telescope. I will use this to back my arguments by larger telescopes for which the data can be found from the article 'Efficient Follow-up of Exoplanet Transits Using Small Telescopes' by Peter Beck because although the data won't be as accurate(close to the true value) but it will be precise(all data points are close in proximity to each other so have a small uncertainty) therefore precision of data is equally as important.<sup>9</sup> I will then investigate sensors on artificial satellites used to capture data which could be taken from conducting interviews with scientists at planetariums as well as journals although there are remarkable telescopes, the sensors will take in the light and analyse the light levels to a high accuracy which I can get from a journal article called 'The Oxyometer: A Novel Instrument Concept for Characterizing Exoplanet Atmospheres' from Ashley Baker.<sup>10</sup>

To assess this data, it would have to be sent back to scientists who can interpret the data and make it meaningful so I intend to use the journal piece called 'Science News of the Year' which tells us how scientists can analyse this – this can be taken from Science News of the Year 2008.<sup>11</sup> Other than this there is a large amount of space debris, which is a massive limitation to this so to analyse this I will use the journal article called 'The Space Debris Problem' from Shenyan Chen.<sup>12</sup> I will also use the journal article called 'Space, the Final Economic Frontier' by Matthew Weinzierl as it highlights socioeconomic factors and environmental factors which can be limiting factors to finding exoplanets such as cost and sustainability, which can be sourced from government websites entirely to see their budget and distribution due to the Freedom of Information Act of 2000.<sup>13</sup>

Finally, another massive and impactful limitation which can be discussed is asteroid mining. A way of solving the resource crisis scientists have been pondering for decades – where I aim to get the relevant information on this topic is from the journal article called 'Asteroid Mining: Ecological jurisprudence beyond Earth' by Reed Elizabeth Loder.<sup>14</sup> A good source of such mining is the asteroid belt as it is in proximity and can be implemented easily without losing resources in the process which I will assess based on gain and loss of materials and economic impact.

I intend to email various astrophysicists working in planetariums across the UK and theoretical physicists to determine their views on the subject matter for example, Brian Cox (Theoretical Physicist in the Royal Society), Neil DeGrasse Tyson (Theoretical Physicist and Cosmologist) and Roger Penrose (Mathematical Physicist). All the journals I will use as secondary sources from JSTOR which has a very diverse set of data and sources from books, journals, photographs, artworks, and scientific magazines which can be used together to make a very complete argument.

- the courses of study or area(s) of personal interest to which the topic relates

Since reading "A Brief History of Time" by Stephen Hawking and after watching "Cosmos: A Spacetime Odyssey" from Neil DeGrasse Tyson, I developed a particular interest in the scientific evolution of the universe especially regarding the formation of planets and star systems and how particular phenomena occur, such as the formation of water and specific atmospheric compositions of planets. I also bought a telescope to look

<sup>8</sup> Whitley, Gigi. "ELECTRO-OPTICAL TELESCOPE PRODUCES FIRST IMAGES OF DISTANT NEBULA." Inside Missile Defense, vol. 3, no. 24, Inside Washington Publishers, 1997, pp. 8–8, <http://www.jstor.org/stable/43971402>.

<sup>9</sup> Beck, Peter, et al. "Efficient Follow-up of Exoplanet Transits Using Small Telescopes." Publications of the Astronomical Society of the Pacific, vol. 131, no. 1002, [IOP Publishing Limited, Astronomical Society of the Pacific], 2019, pp. 1–9, <https://www.jstor.org/stable/26874425>.

<sup>10</sup> Baker, Ashley D., et al. "The Oxyometer: A Novel Instrument Concept for Characterizing Exoplanet Atmospheres." Publications of the Astronomical Society of the Pacific, vol. 131, no. 1000, [IOP Publishing Limited, Astronomical Society of the Pacific], 2019, pp. 1–22, <https://www.jstor.org/stable/26660766>.

<sup>11</sup> "2008 Science News of the Year." Science News, vol. 175, no. 1, Society for Science & the Public, 2009, pp. 16–29, <http://www.jstor.org/stable/20465806>.

<sup>12</sup> Chen, Shenyan. "The Space Debris Problem." Asian Perspective, vol. 35, no. 4, Lynne Rienner Publishers, 2011, pp. 537–58, <http://www.jstor.org/stable/42704771>.

<sup>13</sup> Weinzierl, Matthew. "Space, the Final Economic Frontier." The Journal of Economic Perspectives, vol. 32, no. 2, American Economic Association, 2018, pp. 173–92, <http://www.jstor.org/stable/26409430>.

<sup>14</sup> Loder, Reed Elizabeth. "ASTEROID MINING: ECOLOGICAL JURISPRUDENCE BEYOND EARTH." Virginia Environmental Law Journal, vol. 36, no. 3, Virginia Environmental Law Journal, 2018, pp. 275–317, <https://www.jstor.org/stable/26510760>.

closer at these celestial objects like the Moon and Venus on nights of clear skies and invested time in getting clear shots and using filters to capture specific lights from it to estimate the planetary composition and gases present within the atmosphere and gained lots of experience.

I also am really fascinated by how technology impacts our lives, especially space travel, and it has had massive strides in recent years, so it also really brings out the engineer within me and my interest in CAD/CAM programs helps me understand the picture more. Moreover, because I wish to pursue a career in Aerospace Engineering or Astrophysics at university, I thought evaluating the impact of growing technology on finding Earth 2.0 would not only provide me the fundamental skills needed by engineers and physicists but also the completion of this research topic would be a very intriguing way to learn more.

This topic especially links in with me wanting to learn more and space is an endless abyss just miles out of reach – the biggest mystery to humankind so this fuels my curiosity and can drive my passion. Even though I don't do A-level Design Engineering, I do take A-level Physics, which will facilitate the skills that I will need to that I will need to complete a successful research project. With strong astrophysics focus on my research I thought of looking at the A -Level Physics specification. Although it does go into some depth on space and redshift I will have to research more into this process as well as blueshift and this research can be mostly done on YouTube and research journals to further investigate advantages and disadvantages, as well as figuring out how the mechanism functions in the first place.

Furthermore, since I am studying A-Level Computer Science it will allow me to discuss the impacts of computer simulation within the improvement of technology and will allow me to demonstrate this by using separate algorithms. Additionally, I also study A-Level Further Mathematics, and this can play a huge part in understanding mathematical constraints when finding these exoplanets. This could include the very famous 'Drake equation' and rearranging and adding new variables which changes the equation to fit with purpose.

- my intended product

My intended project is a 5000-word research essay which assesses how technology is helping us to locate Earth 2.0, with several views from different subjects on the same topic from mathematics, physics, cosmology, and computer science path-finding algorithms. My objectives will take the form of more specific supplementary questions, which I aim to answer through extensive research using the sources and literature review. Some of these questions could include 'How scientists locate separate habitable exoplanets?' and 'How can scientists find compositions of exoplanets and find their habitability?' are among some of them. In specific I want my objectives to be related to the mathematics as to how we are able to quantify space, how the first telescope led to astronomical instruments to become so advanced, investigate how the impact of sensors in detecting exoplanets, how scientists get such accurate photos of space and from this I want to see which area in the night sky has the highest potential for habitable exoplanets.

I intend to achieve these objectives by using my sources to investigate each question in turn during the research process, hence allowing me to evaluate my findings and subsequently formulate judgements in my written project. I aim to centre my conclusions on how the technology helped us locate habitable exoplanets and super-habitable planets in unique star systems in both an astronomical and practical engineering distance to travel towards in the distant future. I hypothesise that, despite the difficulty that investigating some questions can be, the rate of which technology is advancing, and its rate of predicted growth can locate - in depth - not only habitable but also realistic goals which will get us to these planets, whether it be fly-bys, rovers, orbiters and/or human exploration. Therefore, my principal aim is to test this hypothesis and conclude how this technology is helping us find a duplicate of Earth or better, with the objective of understanding the cosmos and how this stride takes us a step up in human understanding of the unknown and type of civilisation we recognise ourselves to be.

Provide details of the courses that you are currently studying

Qualification type	Awarding body & subject
eg A-level, Modern Apprenticeship, BTEC	eg AQA Mathematics, OCR Computing, WJEC English
A-level	OCR A Mathematics
A-level	OCR A Further Mathematics

A-level	AQA Physics
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Qualification type	Awarding body & subject
A-level	AQA Computer Science
Click to enter text.	Click here to enter text.
Click to enter text.	Click here to enter text.

**Candidate number**

**Candidate's full name**

Dhruva Teja Turaga

Click to enter text.

Click here to enter text.

Click to enter text.

Click here to enter text.

**Notice to candidate** You must not take part in any unfair practice in the preparation of project work required for assessment and you must understand that to present material copied directly from any book or any other sources without acknowledgement will be regarded as deliberate deception. If you use or attempt to use any unfair practice you will be reported to AQA and you may be disqualified from **all** subjects.

**Candidate declaration**

I certify that I have read and understood AQA's Regulations relating to unfair practice as set out in the notice to candidates above.

Candidate signature.

Date 31 March 2022

Candidate number

Candidate's full name

Dhruva Teja Turaga

## Part B: Supervisor's comments on candidate proposal

### To be completed by the supervisor

Please comment below on the validity and feasibility of the candidate proposal (Part A) as an Extended Project

	Supervisor's comments
Indicate the relation to, and development/extension outside of, the main course(s) of study or interest	Dhruva has a very clear passion for this subject, fuelled through his extensive wider reading and research, and an aim to pursue this at a higher level at university. Although he studies A-level Physics, he has identified that his project goes beyond the specification and into the realm of hypothetical advancements in the field.
Comment on the suitability of the proposed initial sources and research base	Dhruva has identified a clear set of resources to begin with, which he will no doubt develop as his project progresses. He has begun to show critical analysis of their suitability and merit, and this provides a strong foundation from which he can build a credible and relevant research base.
Confirm that the project is feasible in the proposed timescale and/or indicate any potential difficulties that may prevent the candidate from meeting the assessment objectives	Dhruva shows a clear progression of ideas, from identifying why space exploration is important, to analysing the strengths and limitations of technologies which may enable humankind to locate Earth 2.0. He has clear parameters which he aims to investigate, using both primary and secondary research. Should Dhruva be able to collate this data in a targeted way, it should prove an interesting and manageable project. I do not anticipate any difficulties for Dhruva in meeting the assessment objectives and deadlines, should he maintain focused in his approach to his research and analysis.

Indicate the expected format of the project product that will be submitted for assessment

- ☒ Research based written report
- ☐ Artefact (for example prototype, model, artwork, scientific investigation, creative writing) plus written report

Is the project a contribution to a group exercise? ☐ YES ☒ NO

If Yes, confirm that there is a defined individual contribution by the candidate ☐ YES ☐ NO

List the **other** group members below.

Candidate No. [Click.](#)

Candidate Name [Click here to enter text.](#)

Candidate No. [Click.](#)

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Candidate Name [Click here to enter text.](#)

Supervisor signature.

Date [Click here to enter a date.](#)

**Candidate number**

**Candidate's full name**

Dhruva Teja Turaga

## Part C: Centre coordinator's approval of candidate proposal

**Supervisor's name**

Ms R Sanders

### To be completed by the centre coordinator

If you are acting as both the Centre coordinator and the supervisor, please seek counter signature from a senior colleague

Centre coordinator's comments on the feasibility and acceptability of the proposal (parts A & B) as an Extended Project

This is a very exciting and ambitious proposal, but the supervisor gets it right when she says that it needs to be a targeted and focused project.

Dhruva's Candidate Proposal indicates that his literature review will be wide-ranging – understandable given the complexity of his proposal – but I think it would be wise for him to consider, at Planning or Mid-Project Review, whether his idea needs to be narrowed even further. There are so many aspects of technology to consider for finding exoplanets, both on Earth and from space-craft launched for this purpose, that Dhruva may find that he has to be selective about what he can and cannot include.

There is no doubt about the acceptability of the academic demands and originality of such a project proposal, but its feasibility will very much depend on how manageable his plan actually is for completing the project, both within the time-frame and to the given word count target of 5000 words.

☐ Approved

☒ Approved subject to the implementation of the centre coordinator's recommendations

☐ Resubmission required

**Centre coordinator's name**

Mr A. Mitchell, cross-moderated by Mrs S. Shales, Head of Sixth Form.

Centre coordinator signature.

Date 28 March 2022

## Planning review

### To be completed by the candidate

This page records your outline plan once your proposal has been approved.

My next steps in planning, researching and deadlines that I will set myself. What I intend to do, by when, what resources I will use and how I will implement the recommendations of the centre co-ordinator (where appropriate).

At this point during my project, I have made considerable progress in the research and literature review element of the process and have come up with a general structure of my essay and beginning to answer some major questions relating to this field of cosmology on habitable planets and 'exoEarths' from the research collected. On my literature review so far, I have addressed research methods which go into determining the habitability of exoplanets and changing their status to a potential Earth 2.0. During the analysis of my research, I made a high level of notes, statistics and different mathematical guidelines followed which will be useful for the formation of my essay further along. I have also started to look into astronomy as a way of understanding this topic at a higher level and recognised the importance of certain factors which can make seeing celestial bodies clearer and with much more magnification.

Through my analysis I identified trends across observational data from ground-based telescopes. This includes the Giant Magellan Telescope (diameter 24.5m) and the European Extremely Large Telescope (diameter 39m). These telescopes allow scientists to characterise a planet's atmosphere which, after detailed data analysis, have allowed me to conclude that they are of such high calibre than even some space-based telescopes as they can have a much larger size, much more frequent data recall and easy to maintain for years on end. From that point, other methods included compiled data from scientists who undergo analysis of data of infra-red spectroscopy to gaze at luminosity values and from this determine movements, sizes and even types and lifetimes of host stars but have disadvantages of their own such as communication problems during different orientations and point in space. Finally, to simulation data where computer programs have been used to track the local group and solar neighbourhood using machine learning and AI all based on python. Since I study A-level Computer Science and have had a chance read thoroughly and understand its importance in the monitoring of certain exoplanets and even simulating their lifetime effortlessly.

I have also decided my project contents will be laid out as followed:

#### Literature Review

Introduction onto why humanity first took interest towards the stars – in this section I aim to look at the uses of astronomy for Egyptians, Mesopotamians, the Indus valley civilisation where it is still being used in Hindu astronomy today through past the Greeks to Galileo and Newton who by that point developed the mathematics to quantify discrete distances in space and this Newtonian Calculus which has helped us gather the movement of celestial objects in the past.

The development of the first telescope by Galileo and how he confirmed the Copernican theory of the solar system. This also includes what and how he made observations of Jupiter's moons and gave birth to ground-based telescopes.

The development of different types of telescopes and advantages and limitations of each other and how they are used which I can reference from my literature review.

Conduct primary research from my own telescope to observe celestial objects to back up arguments of ground-based telescopes in the discovery of habitable exoplanets from this I will either use computer simulation programs or create my own algorithm in python to find its distance as well as mass and radius even if it is just the moon. I should gain the skills conducted by scientists who do the exact same thing but with much more refined instruments.

The investigation and development of sensors and the massive lens on space-based telescopes which also analyse light levels and give sensor readings to scientists.

The largest limitations of space-based telescopes which links to the unpredictability of space. Socioeconomic, environmental and political factors that limit the development of technology and space discovery.

Conclusion to the overarching question of is the rate of technological advancement every guarantee us a new Earth.

I have also created a Gantt chart which, I believe, will help me keep my workflow organised. As time progresses, I know they could change due to different commitments but this method will ensure I keep at a fast pace and don't slack off so that my EPQ can progress as effortlessly as possible.

During the research for the questions so far, I have been very careful to ensure I have evaluated their value in my research before analysing them as well as keeping a full references document with comments so that the writing of my essay will be quicker and more manageable as well as backing up every change I make in any document.

After the planning review, I will focus on achieving my other objectives through the analysis of my resources such as sending separate email questionnaires to different professors of cosmology at different universities which helps me in my primary research as I have sent questions which can't be found as they can be purely subjective based such as most effective way to monitor star brightness from professors with degrees in space instrumentation like Professor Richard Massey. After which I will finish my literature review and formally start writing my essay based on the titles I have provided above and making the baseline structure. The dated plan which I am using to divide my time between different areas of my EPQ can be seen in my Gantt Chart – which I have progressed through time as time frames became more clear and started each week on a Monday as I intend to do a bit of work afterschool everyday but some objectives might take more time so I will probably come back to it like the conclusion of my primary research with my telescope. Due to the fact that the UK has very unpredictable weather it might take longer if the nights are more cloudy or the moon is in different phases so sometimes it won't have the highest light reflection so the Gantt in this part is much more varied compared to other parts.

Up to this point in my EPQ, I have had success in finding credible and useful resources for my project and analysing these resources in reference to my objectives and potential areas for debate within different questions. An area where my project has not gone the way I intended is the lack of varied resources as most are dissertations and theses from PhD or graduates which do provide some insight into the field of instrumentation but isn't varied enough however this wasn't too much of a setback as I have been reading books like the Space Knowledge Encyclopaedia and that I have had the thought to contact different professors by email as well varying my primary data and get their insight into my project.

I am thoroughly enjoying the EPQ process because it gets me to think about my different areas of passion and investigate new and interesting areas of cosmology and is very encouraging for my future prospects of aerospace engineering at university.

My summary of the comments and advice from my supervisor

After talking with my supervisor, I decided that my EPQ title needs to be narrowed further as there are so many aspects of technology which are just too vast to explore and stay within the word count and time frame. I agree with this assessment.

Before this change, I used many different types of technology which didn't specially relate to the location aspect of the project but the whole space satellite as a whole which include communications to and back from Earth, propulsion of different methods and different designs of the satellites which I could model and 3D print and show their aerodynamic ability but soon realised how they had little to no significance to the location aspect of the search for a habitable exoplanets.

Due to their high prevalence in my project I soon summed that these were irrelevant to the main research question which was "How is technology helping us in locating Earth 2.0?" and that the most important aspect which aids in the location of an Earth 2.0 is the main telescope whether Earth-based or space-based which was indicated in most of my research and documentation and upgrading the telescopes over time by sending new satellites is what is helping us get a better understanding of exoplanets and their habitability.

Another aspect we discussed is how would I manage the time throughout this project as I have had a lot of time to research and collate my findings but need a structured way in order to make sure I can make each section of the essay as developed and detailed as possible which would mean I have to dedicate more time at home and at school during free periods and study periods but as I take 4 A-Levels this would need to be very specific as I only have 10 a fortnight.



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**Candidate's full name**

Dhruva Teja Turaga

Modifications I have made as a result of my discussion with my supervisor and/or the comments from my centre coordinator

Although my supervisor seemed pleased with the majority of my planning, I have taken into account the comments on the subject of my EPQ title and I have changed the subject of my EPQ from technology to astronomical instruments. This filters the technology I am researching to just telescopes and sensors which is the most crucial part and the basis of my highlight of my research. This also means there will be enough to talk about but also not changing my title too much so my research doesn't go to waste.

I have also used 2 telescopes of different types (reflector and a refractor) with an equatorial mount (which means they can be moved in slight variations in degrees so can move across the night sky more delicately. This also means researching about this aspect of technology makes much more sense and I can compare pictures and readings I have taken with equivalent ones taken by NASA or ESA. This is so that I can discuss the differences and changes in my pictures as well as have the ability to merge my findings to get more accurate data.

In terms of time management, I have incorporated many aspects into specific days such as making some of my free periods specifically for my EPQ and dedicated an hour at home everyday so that even little progress I make will still contribute to the overall result. Also, I have been updating and looking into Evernote quite commonly so whenever I get an idea it will be recorded so I can have a reference when I am writing.

To see the changes over time I have made a Gantt chart where I state how I will distribute my workload on this project across weeks and months in advance so I can have proper deadlines ready so can focus on only one thing.

With these changes I intend to complete my mid-project review by the week ending 9<sup>th</sup> May. This allows enough time for me to add more to my literature review and start the methodology section of my EPQ. I would hope to believe the professors I have emailed respond within the coming days so if they do I aim to complete the analysis on it as well into my literature review. By the time I complete my mid-project review it should equip me to develop better points and discussion to my sources especially with disagreements and it will help me develop my arguments better.

Date 24 April 2022

## Mid-project review

### To be completed by the candidate

This page records your outline plan when you have completed your research.

Is my project following my original plan? How has my plan developed?

My project is largely following my original plan and hasn't drastically changed in terms of context but it has definitely developed in some areas. Firstly, I have further considered the primary investigation that I will incorporate in my project and started forming a rough methodology on how to do so. The primary investigation was the part of my EPQ I was most fearful of as it involved spending lots of time outside of school and discovering and finding celestial bodies without the aid of any book or manual, but whilst doing it I have learned it wasn't that hard once I got started and I have learned skills to make what I do much easier. In this section I will ensure that my essay at this part will be analytical throughout to provide a clear and substantiated views in my methodology. My objectives for the methodology section are to follow the scientific method where I will keep certain variables constant and manipulate others – for my experiment specifically it will mainly be the magnification and the different celestial objects on two different types of telescopes.

Furthermore, I have made an amendment to my question throughout this process from the use of technology to astronomical instruments which makes it much more examinable and see the difference between celestial objects which is mostly the primary focus of my EPQ in total and not the journey to the new Earth itself. As I outlined in my plan, I really wanted to delve into the field of cosmology instead of the different engineering disciplines which could take very long to plan, investigate and conclude. Also, regarding my question, I have emailed many professors from universities to get their input on this but sadly none have responded yet but to prepare I am going off my instinct and discuss the independent variables in my methodology and talk about how the readings I have got influenced by EPQ. If I still do not hear back from professors, I intend to exclude it from my literature review and not compare it and go of pre-existing literature.

In addition to this, on my literature review I have created a detailed plan in executing it and regarding which resources to use at a certain time and place. By creating a table of contents with sub contents indicating what I am doing, I also created a separate word document which dictates what sources I am using at the specific time. This means that I can leave majority of the references till the end as long as I keep track of them and add them in securely. This is also much more time efficient as I have realised I don't have to stop and write the references every time I use them which helps me in the analysis of the different sources within the footnotes near the end. Included in this topic I have laid out, I made my essay quite versatile in the sense that it isn't very hard to implement and change the footnotes as they are saved to an external file and I have been using Evernote quite profoundly as it has helped me manage the time frames for all the projects and help me add ideas which I have suddenly had so that I won't forget them especially regarding the experiment and how I could improve it.

The deadlines that I have set for my research are largely the same but with the FUPG revision piling up on me as well the amount of depth of work I have to reduce the time I can spend on each part of my EPQ. This likely means I have to increase the time for each of my pages in small chunks more frequently which will allow me to analyse more thoroughly and allow for the most efficient and optimal revision-EPQ balance. This would mean I have to finish my literature review for my EPQ before the final week of May which will allow me sufficient time to write about the methodology and conclude my research. After the exams, to fully check up on and make improvements to the essay, I will have to check deeply on the structure so that it is satisfactory and make sure my points are well informed and referenced adequately.

I have also developed quite a judgement on how my research has changed and how it's both complementing and challenging my original hypothesis. Since my hypothesis is mainly supported I can see how the conclusion will be shaped and how certain factors have changed my investigation whether drastically or minimally.

My summary of the comments and advice from my supervisor

Through the correspondence with my supervisor, initially we discussed some positives, for example, how my primary research has been narrowed down significantly so that I could fit my conclusions and methodologies in my entire essay and achieve my goals at the end of my essay without it exceeding the word count. My supervisor also commented that I have had a strong organisation and organised my time effectively so far this is mostly using my Gantt chart I have kept updating. By using the Gantt chart, I can see what I must do, could do and when, which is really effective at time management, and I have been updating it ever since I got the first draft of it due to different circumstances. I have also set SMART targets by adding specific dates onto each of the pieces of my work and I have set attainable goals which I believe I can do within the time frame.

The main real problem within my essay so far is my literature review as it is much broader than I anticipated, this could raise issues with the organisation of my ideas as it might make it much more convoluted that what it needs to be and makes my research more idea based which I do not want. From this, I looked back and saw I could reduce my focus away from the history of cosmology as it hasn't got a clear reference to the main research in the literature reviewed has no correlation to the use of these astronomical instruments. Moreover, I also created a higher emphasis on the different existing telescope technologies which as it could mean my essay would flow from point to point gradually. This also means I could make my EPQ much more versatile and come to an all-rounded conclusion since I could discuss more in the literature review about different parts of technology making sure my EPQ has a centralised concept.

Modifications I have made as a result of my discussion with my supervisor at this stage

Resulting from this conversation, upon realising that my literature review will exceed the 2000 words I have set so far as a limit I will slightly condense and cut out certain parts of the history of cosmology section due to it not having an immediate connection towards the focus of my research. Building up on this point I have also come to the realisation that I need to focus more on these different technologies and how they have evolved over the years and emphasise that aspect more in my EPQ which will make it clearer.

Apart from this, the only task I have to continue doing is following the procedure of my EPQ by sticking to my Gantt chart and keep setting SMART goals and deadlines as I go forth with the project especially to the primary investigation stage of my project. By continuing to do this, I will have a much clearer insight into the future, and I could also be thinking how the rest of my essay will plan out. If I get any more ideas, then I can update Evernote where I have distinct notes as my project progresses and if I continue this process then I can have the log of my ideas which I can go back to near the end and check if my objectives have been met. If they have then I can reference them within my conclusions and if not, then I could also reference how I could improve upon it.

My final title and agreed form of project product

My final title for my EPQ is "How are astronomical instruments helping us in locating Earth 2.0?" and I intend to write a 5000-word essay which I will support with a presentation of my findings.

My planned next steps to complete my project

The next step for my project is to continue writing my essay and progress past my literature review and start the write up for my investigation with the independent variables and collected data I have gathered. This, in my opinion, will be the hardest part of my entire project because it would mean following the scientific method very thoroughly. The analysis section as well is (at this current stage) going to be the hardest to continue since I have tried different approaches, but none work as of yet. But as illustrated from my Gantt chart – I have quite a significant amount of time before the due date as well as the holidays as well to keep improving and creating graphs. It may also be useful at this stage if I store the different sections of the essay into different word documents so if I were to suddenly change the structure of my essay it can be done with ease especially since this stage of my project still looks quite complex with the research citations.

Once I begin my draft with the introduction and methodology I can start to visualise my essay better and see how it progresses over time and keep updating my Gantt chart and then start each section in turn ensuring that they flow onto each other. This will create the idea that the essay can be taken as a research paper and not different

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topics being talked about. My conclusion will then summarise my ideas as well as my primary research in such a way that it can elaborate which parts scientists see as an effective strategy to finding exoplanets and which one is flawed either economically or practically. This will give a definitive answer to my overall question "How are astronomical instruments helping us in locating Earth 2.0?".

Date 26 June 2022

## Project product review

### To be completed by the candidate

This page records the (near) completion of your project product. Outline the successes, failures, additions and/or changes you made as you followed the plan in your mid-project review

Did my project follow my revised plan (from the mid-project review)?

My project largely followed my revised plan as I used the same structure and analytical conclusions as I had hoped and has progressed significantly quickly from the mid project review. From feedback throughout my project, I felt as if my analytical reasoning and judgement skills really improved. Before talking to my supervisor, analysing my primary research was quite a challenge as I wasn't used to the layout from which you should talk but after the advice about creating criteria it became easy to see how to flow to the next sections.

Looking at the sections I have done chronologically the successes of my essay definitely fell where I talked about my secondary sources and how they make an impact to finding habitable exoplanets. This is true especially for the sections talking about humanity's interest into the night sky and the types of telescopes which are in operation like the Hubble and James Webb. These resources were very varied which I was quite surprised to find since most resources I found on google scholar mostly contain dissertations rather magazines or books. Another key success is the overall structure of my essay since I was initially talking about the literature review and then my primary analysis section with the conclusion. Now, after completing a proper research paper which sums up my findings and adds an overall conclusion, I see a much better view of my EPQ and it shows my level of understanding of the topics I have at hand as well as adding more context to the arguments I proposed.

The main challenge during my EPQ was the time frame. With the stress of doing all four of my A-Level subjects – you have very little time with an EPQ essay but with my Gantt chart and heavy organisation I could find time aside to focus on this project. This got much harder as it got closer to the FUPGs as I couldn't devote as much time but as soon as the deadline got pushed back, I could very confidently finish this project. However, during this time another challenge sparked, the length of the whole essay. Due to all the interlinking stages of my essay – I kept writing how I felt my essay should flow but then this drastically increased my word count, and it suddenly became very large which meant I had condense to a great extent which required much more time. This is what I predicted in my mid project review, but I didn't quite expect the length to go so far out of hand that I would need to condense this significantly.

My summary of the comments and advice from my supervisor at this final stage

After reading my essay draft, my supervisor seemed content with the depth of my research with every point within my essay going into extreme detail and the credibility of my resources throughout the essay. As part of our discussion at this point, my essay was much over the word count by a very significant amount (about 3000 words over). From this I was suggested to cut parts of my essay from which I felt that didn't have a direct influence as to my question. I was recommended to reword certain sentences in order to make my essay more concise and only cover the main details of the research up to my methodology and elaborate more about what I did rather than elaborate on secondary sources. Furthermore, a piece of advice given about the figures is that they could be more effectively displayed and explained if I added a textbox with a hyperlink and state what it is about. This was due to the high technical knowledge needed the sources to make sure the points I have made are conveyed in the easiest and most efficient way possible without adding great significance to the word count. Another point which was brought up was my use of colour images and how I should print off my essay since it contains many images which use colour referencing to signify certain compositions of stars and what they represent. I have decided to do this since it also makes my analysis effective if I can link the colour to their effects so anyone reading can see exactly what I am trying to convey.

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**Candidate's full name**

Dhruva Teja Turaga

Modifications I have made as a result of discussion with my supervisor at this final stage  
Do I need to do anything else to complete my product?

I agreed with supervisor for most aspects on how to edit my essay so that it will be within the word count, I have decided to completely remove the section about the Dutch perspective lens and how Hans Lepperhey and Galileo founded the telescope, this was heavily considered by me over a long period of time since, at the beginning, I felt as if this was vital as it leads onto how telescopes are made today. This reconsideration came from the fact that it didn't quite link directly to my main question, it was just additional knowledge which was useful for Earth based telescopes. From this reconsideration, I have summarised the points I have made in the section about Galileo's first telescope to ensure that the data I have collected is still of use and allows me to give a brief introduction to the Earth based telescopes. Consequently, this reduced my word count by a large margin and enables me to get one step closer to the necessary word limit as well as making my essay flow appropriately making sure all the points are noted down. I can also keep the whole of my methodology section in my essay as I feel like this is very vital since it shows most of my conclusions and how I used my secondary research to form hypotheses and conclusions.

Going onto the figures, I have decided instead of using footnotes as the primary way to cite the sources of pictures that I have used, I have actually put in a hyperlink of the page in which I got the picture as well as a brief description as to what it is. Although this increases my word count slightly by adding text boxes, I felt like this introduces my sources better and made my essay flow in a more effective manner.

I have also decided to print off my essay, my presentation and everything else I use throughout my project in colour as opposed to black and white. This, I feel, is very crucial in my project because my pictures are taken in the night sky, there is only so much editing I can do to make it appear bright but still keep the stars in the picture with their correct colour. Although this uses lots of ink and paper – I feel like my essay and overall argument will be expressed better.

Finally, to complete these tasks, I had to update my Gantt chart so that I can finish everything before the deadline. Due to the engineering exam coming up as well as managing 4 A-Levels this is what I need to get right so that I can manage my time in the best way possible. Now, I just need to implement all my changes to the essay as well as change the figure numbers, keep a note of which references I have used and which I have removed so that my sources are credible and effectively used in my essay. Along with this, since I do not take any literary subjects, I need to heavily check my spelling and grammar as this is what is most challenging as I need to check if the sentence is vital and shrink certain parts which aren't directly related to my essay using a range of sentence types to convey different meanings.

Date 22 August 2022

## Presentation record part A

### To be completed by the candidate

This page records your presentation and its preparation.

Planned format of my presentation (eg timing, audience, use of visual aids, slides, use of notes, etc.)

My presentation will take the form of discussing how I have first thought of this question then to my literature review which I will explain what I have looked into to get an insight to this project and then talk about my hypotheses, methodology and show the pictures which I have taken on various instruments. In order to make my project understandable to anyone who has no clue about Physics and astronomy, I have created a handout which I will give to each member who attends my presentation which outlines what the title means and some history of the field so that the sources I have read on in my essay do not go to waste as I had to remove them so that I could have more space and make my essay flow better.

This is then ended with a conclusion and how my successes, challenges and solutions have affected the potential of my project. I have made a PowerPoint to accompany my speech, with slides which have concise bullet points of the key facts I am going to discuss about the specific slide. I have planned for my presentation to be around fifteen minutes, leaving enough time for questions at the end for five minutes.

My project contains quite a lot of pictures as I have taken and labelled so that the listeners can see the work I have achieved over the breadth of time and what my research concludes. I wish that some of my audience contains people who have an understanding of maths and physics so that I do not need to explain some obvious concepts within my presentation but have a discussion at the end if any questions do remain.

Planned content of my presentation

In my presentation, I have created various slides detailing the steps I have taken in my EPQ process before completing my research. The title page of my presentation shows a rotating Earth so that the audience can see what features the Earth has before I even start talking. I feel as if this is an effective way to make the audience enter the mindset of a scientist looking for in an Earth 2.0. The next slide I have decided would hold why I chose this subject including the books I have read and videos I watched which got me interested in this specific field to do my research project. The next slides would include the meaning of the question, which will allow the audience to understand why we need to look for an Earth 2.0 and with what astronomical instruments. This is so that they can understand why this question is very important for the future.

From here I talked about the aims and objectives throughout my research and what I planned to investigate, my hypothesis for the answer to my main question and my methodology which highlights the factors I analysed and looked at and how I did it.

I will then include five slides talking about my secondary research and what I read up on, examined and analysed which got us to the stage of exploring exoplanets. This specifically includes the titles in my essay, how we got into astronomy, earth-based telescopes, the development of sensors, space-based telescopes and how we are slowing the search for exoplanets. I will include points from all the papers I have read up on and included in my essay. Then I will start talking about my primary research, will start of by talking about how telescopes are used to get images of planets, initially discussing my hypothesis and recapping how I will analyse the photos. I will also talk about the devices I have used and then show the pictures which I have taken. I will house a slide just showing pictures so that I can elaborate, in my speech, about the factors I have analysed and give my sub conclusion. Then, I will talk about the part of the sky with the highest probability of containing a habitable exoplanet following the same procedure as the previous slide. I will explain how I have taken the photos and what factors I have considered. I will then show the pictures of Vega and the Andromeda galaxies I have taken comparing it with the one taken by the James Webb. In this I will talk specifically about the factors I have considered and explaining that I have kept everything else constant like wind or location making an overall sub conclusion.

Finally, in my conclusion I will outline what I have realised after reading secondary sources and how it prompted my primary research and what my overall conclusion is to the main question. My final slides will show my evaluation, detailing what I think went well, the challenges I have faced with specific solutions as well as what I would do differently. To finish my presentation, I have included an "Any Questions" slide and then a slide with references for my pictures and sources I have looked at in great detail that I have used in my PowerPoint.

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**Candidate's full name**

Dhruva Teja Turaga

Modifications I have made as a result of rehearsal and/or discussion with my supervisor

After displaying my PowerPoint to my supervisor and running through it, I realised it was quite lengthy and I could not fit the whole presentation within the time space. After hearing advice from my supervisor, I reconsidered some areas in my PowerPoint. One point was the necessity of the history of astronomy. I felt like this was necessary for my essay because it allowed it to flow smoother and have an introduction to the idea of Earth and space-based telescopes. To counter this I have created a handout, this enables me to help the audience understand how Earth-based telescopes first came about and it allows me to simplify my PowerPoint as I can have it containing why I chose to do this question with pictures explaining what it means.

I have also been told to create a flashcard speech which has everything I need to say. Especially with the short time that I had I needed to create the script and revise it efficiently, so I decided to take specific parts of my essay and say those points rather than create a completely new script. My supervisor also suggested the slides including my secondary sources contained too many words to be read by the audience so I included these points in my speech so that I can elaborate and improvise if needed.

Date 20 September 2022



Candidate number

Candidate's full name

Dhruva Teja Turaga

## Presentation record part B

### To be completed by the supervisor

Record and comment below on the delivery of the presentation

	Supervisor's record/comments
The nature of the audience (include numbers of staff, students and others present)	<a href="#">Click here to enter text.</a>
The nature of the presentation (include use of notes, use of display items, and use of presentation software)	<a href="#">Click here to enter text.</a>
Comment on the content and delivery of the presentation (for example clarity of ideas, structure of presentation, pace, engagement with audience)	<a href="#">Click here to enter text.</a>
Comment on the response of the candidate to questions that demonstrated understanding and grasp of the project and/or its production. <b>Give examples of questions asked and answers given.</b>	<a href="#">Click here to enter text.</a>

Supervisor signature.

Date

[Click here to enter a date.](#)

## Summary and reflection

### To be completed by the candidate

This page records your summary, reflection and evaluation when you have completed your project product and given your presentation.

Some questions you may wish to answer in this section include, what have I learned from completing this project? What new knowledge or expertise have I enjoyed or found valuable? What are the strengths and weaknesses of my project (including planning and organisation)? What skills have I improved? What changes would I make if I undertook such work again? What advice would I give to others undertaking such a project?

I have thoroughly enjoyed the opportunity to research a topic that I am passionate about in immense depth. With my scientific curiosity I have been able to become more educated about the scientific method and the process by which scientists make advancements which change the world. I hope that my presentation along with my essay will educate others about the future of humankind and how the advancement of technology will help us understand the universe better.

One of the main reasons behind why I enjoyed the EPQ so much was the process I followed to get the stunning photos of the stars and the Moon. Along with this, I had lots of fun learning about referencing with Harvard and footnotes and how to use them effectively to make sure I cite everything I have read. Before I started the EPQ I had no idea how to start research projects but now I understand how to credit sources and make me better prepared for any assignments I get in the future. I also learned a lot about the importance of choosing credible sources which I didn't really pay attention to in the beginning. I also gained a new ability to manage my time efficiently through the writing of my essay. Whilst doing 4 A-Levels along with the revision for the exams, work experiences and the goal of getting into Cambridge I had to manage my time so that I can score and receive the best predicted grades in all my subjects. This, I feel, will set me up for university because the deadlines and tasks are much harder and you need a much better way of looking at projects which I feel the EPQ has given me.

Furthermore, I have developed numerous literary skills through the EPQ process. For example, the ability to analyse extensively any information I have been given and from a source infer and write an overview and the knowledge I have gained from it. This also helped me to foster planning skills when faced with many pressures of research, exams, and extra-curricular activities simultaneously. This was especially true with my Gantt chart which I will definitely use in the future if I have a large research task. I also expanded on my critical thinking skills when I had major setbacks in my process and helped me to use skills I learnt in other subjects to aid me with this EPQ. This is exemplary when I had to 3D print a mounting bracket for my telescope as it broke which needed me to create a 3D model in Solidworks as it was a bespoke design which couldn't be shipped to the UK.

I feel like my strength in this project was the ability to find a vast number of sources of different types. From these I could go in so much detail about statistics from datasets, secondary sources from books, magazines as well as the new journal articles and university dissertations I have read. Although, it was a challenge to edit my sentence structures and know what aspects were vital to keep as it led to an answer to my main question and what to remove in my essay since I do not take any subjects which this is useful in but with time I felt like I got much better at this.

If I were to do this project again, I would add more to my primary research and talk to actual professors in the field so that I know the information I am receiving is accurate as well as up to date and learn more about the in-depth physics behind how everything works. Although I sent emails this time, with more time I would go to universities and request if I could talk to the professors and even present my findings. Adding onto this, I would have given myself more time to prepare for my presentation, this was due to the fact that I was given a short deadline to create it from which I had to work very late to finish it off but given longer time I know I could create a more comprehensive overview and report of my findings. Some pressures I definitely experienced were the FUPG exams which coincided with the most important part of my EPQ, the essay. Following from that point, I would have ideally completed my research much before the FUPG exams to alleviate some pressure around this busy time.

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**Candidate number**

**Candidate's full name**

Dhruva Teja Turaga

My advice to future students who want to get involved with the EPQ is to decide on the title very quickly so that you have no issues starting quickly and at a good pace as well as don't have a lot of commitments whilst doing an extended project. As I am doing 4 A-Levels as well as doing a DofE Gold and becoming deputy head boy I have definitely felt pressures throughout the year, but I managed, somehow, and I felt like you should have some priorities before doing this and not overwhelm yourself. Finally, the most important thing I feel is to just enjoy the topic and commit to it as it is very rewarding in the end. You will learn a lot about yourself, your interests and others and you expand the database of your mind which I didn't see whilst coming into this but am grateful that I have experienced.

**Critical Source Analysis**

Title	Resource Type	Full Reference	Weight in project	Credibility
An Empirical Critique of Two Versions of the Doomsday Argument: Gott's Line and Leslie's Wedge	Journal Article	<sup>1</sup> Sober, Elliott. "An Empirical Critique of Two Versions of the Doomsday Argument: Gott's Line and Leslie's Wedge." <i>Synthese</i> , vol. 135, no. 3, 2003, pp. 415–30. JSTOR, <a href="http://www.jstor.org/stable/20117377">http://www.jstor.org/stable/20117377</a> . Accessed 12 Aug 2022.	Very minimal as history of astronomy wasn't the main focus of my essay	Somewhat credible as it is a critique of ones opinions but since it does not have a heavy weightage it can still be used
Encircling Astronomy and the Egyptians: An Approach to Abraham 3.	Journal Article	<sup>1</sup> Muhlestein, Kerry. "Encircling Astronomy and the Egyptians: An Approach to Abraham 3." <i>Religious Educator: Perspectives on the Restored Gospel</i> 10.1 (2009): 6.	Minimal as history of astronomy wasn't the main focus of my essay	Credible because it is sourced from Religious Educator which has been peer reviewed
Historical eclipses and the variability of the Earth's rotation	Journal Article	<sup>1</sup> Morrison, L. V., and Francis Richard Stephenson. "Historical eclipses and the variability of the Earth's rotation." <i>Journal of geodynamics</i> 32.1-2 (2001): 247-265.	Minimal as history of eclipses wasn't the focus of my essay	Credible as it is a peer reviewed source from Durham University
Detection of extrasolar planets by gravitational microlensing	Journal Article	<sup>1</sup> Bennett, David P. "Detection of extrasolar planets by gravitational microlensing." <i>Exoplanets</i> (2008): 47-88.	Quite heavy as it is a technique used to determine my factors in my methodology	Credible as it is from a chapter from a peer journal
Microlensing searches for exoplanets	Journal Article	<sup>1</sup> Tsapras, Yiannis. "Microlensing searches for exoplanets." <i>Geosciences</i> 8.10 (2018): 365.	Quite heavy as it is a technique used to determine my factors in my methodology	Credible as from a geosciences journal article reviewed by Universität Heidelberg
Radial velocity techniques for exoplanets	Journal Article	<sup>1</sup> Lovis, Christophe, and Debra Fischer. "Radial velocity techniques for exoplanets."	Quite heavy as it is a technique used to determine my	Credible as a journal article reviewed from Yale University

		Exoplanets (2010): 27-53.	factors in my methodology	
Lunar Brightness Variations with Phase at 4.3-MM Wave Length	Journal Article	<sup>1</sup> Coates, Robert J. "Note: Lunar Brightness Variations with Phase at 4.3-MM Wave Length." The Astrophysical Journal 133 (1961): 723.	Quite heavy I used it to understand concepts of the moon	Credible as journal from NASA
Atmospheric dynamics of terrestrial exoplanets over a wide range of orbital and atmospheric parameters	Journal Article	<sup>1</sup> Kaspi, Yohai, and Adam P. Showman. "Atmospheric dynamics of terrestrial exoplanets over a wide range of orbital and atmospheric parameters." The Astrophysical Journal 804.1 (2015): 60.	Quite heavy used in my literature review to understand concepts of atmospheres on exoplanets	Credible as from The American Astronomical Society
Spectroscopic properties of cool stars (SPOCS). I. 1040 F, G, and K dwarfs from Keck, Lick, and AAT planet search programs	Journal Article	<sup>1</sup> Valenti, Jeff A., and Debra A. Fischer. "Spectroscopic properties of cool stars (SPOCS). I. 1040 F, G, and K dwarfs from Keck, Lick, and AAT planet search programs." The Astrophysical Journal Supplement Series 159.1 (2005): 141.	Quite heavy used in my literature review to understand concepts of dwarf stars and spectroscopic properties of them	Credible as from The American Astronomical Society
Spectroscopic direct detection of exoplanets	Journal Article	<sup>1</sup> Birkby, J. "Spectroscopic direct detection of exoplanets." (2018).	Quite heavy used in my literature review to understand concepts of spectroscopic properties and how they are used to detect exoplanets	Credible as peer reviewed source from Springer Nature
High-resolution spectroscopy of extremely	Journal Article	<sup>1</sup> Aoki, Wako, et al. "High-resolution spectroscopy of extremely metal-poor stars from SDSS/SEGUE. I.	Quite heavy used in my literature review to understand	Credible as from The American Astronomical Society

metal-poor stars from SDSS/SEGUE. I. Atmospheric parameters and chemical compositions		Atmospheric parameters and chemical compositions." The Astronomical Journal 145.1 (2012): 13.	concepts of high resolution spectroscopic properties of metal poor stars	
Reflected spectroscopy of small exoplanets I: determining the atmospheric composition of sub-Neptunes planets	Journal Article	<sup>1</sup> Damiano, Mario, and Renyu Hu. "Reflected spectroscopy of small exoplanets I: determining the atmospheric composition of sub-Neptunes planets." The Astronomical Journal 162.5 (2021): 200.	Quite heavy used in my literature review to understand concepts of reflected light from planets	Credible as from The American Astronomical Society
On the Interpretation of beta Lyrae and Other Close Binaries	Journal Article	<sup>1</sup> Kuiper, Gerard P. "On the Interpretation of beta Lyrae and Other Close Binaries." The Astrophysical Journal 93 (1941): 133.	Quite heavy used in my methodology to understand what I have seen in the pictures I have taken	Credible as from The American Astronomical Society
The Evolution of the global star formation history as measured from the Hubble deep field	Journal Article	<sup>1</sup> Connolly, A. J., et al. "The Evolution of the global star formation history as measured from the Hubble deep field." The Astrophysical Journal 486.1 (1997): L11.	Minimal as history of the formation isn't very vital to answer my essay question	Credible as from The American Astronomical Society
Binary Star Synthetic Photometry and Distance Determination Using BINSYN	Journal Article	<sup>1</sup> Linnell, Albert P., Paul DeStefano, and Ivan Hubeny. "Binary Star Synthetic Photometry and Distance Determination Using BINSYN." The Astronomical	Quite heavy used in my literature review to understand concepts of binary stars and identify them in my pictures	Credible as from The American Astronomical Society

		Journal 146.3 (2013): 68.		
Ages of late spectral type Vega-like stars	Journal Article	<sup>1</sup> Song, Inseok, et al. "Ages of late spectral type Vega-like stars." The Astrophysical Journal 533.1 (2000): L41.	Quite heavy used in my methodology to understand stars from the Vega star system	Credible as from The American Astronomical Society
Large optical space-based telescopes	Journal Article Journal Article	<sup>1</sup> Kirichenko, D. V., V. V. Kleimyonov, and E. V. Novikova. "Large optical space-based telescopes." Journal of Instrument Engineering 60.7 (2017): 589-602.	Quite heavy used in my literature review to understand optical telescopes	Credible as from the Scientific and technical peer-reviewed journal "Journal of Instrument Engineering"
COSMOS: Hubble space telescope observations	Journal Article	<sup>1</sup> Scoville, Nick, et al. "COSMOS: Hubble space telescope observations." The Astrophysical Journal Supplement Series 172.1 (2007): 38.	Quite heavy used in my literature review to understand the Hubble space telescope	Credible as it is one of the most cited publication and peer reviewed by The American Astronomical Society
Third-epoch Magellanic Cloud proper motions. I. Hubble Space Telescope/WFC3 data and orbit implications	Journal Article	<sup>1</sup> Kallivayalil, Nitya, et al. "Third-epoch Magellanic Cloud proper motions. I. Hubble Space Telescope/WFC3 data and orbit implications." The Astrophysical Journal 764.2 (2013): 161.	Quite heavy used in my literature review to understand the motions of the hubble space telescope	Credible as from The American Astronomical Society
The three-body problem	Research Report	<sup>1</sup> Musielak, Zdzislaw E., and Billy Quarles. "The three-body problem." Reports on Progress in Physics 77.6 (2014): 065901.	Quite heavy used in my literature review to understand how we founded the Lagrange points	Credible as published in the reports on progress in Physics which is peer reviewed
Microlensing surveys for exoplanets	Research Report	<sup>1</sup> Gaudi, B. Scott. "Microlensing surveys for exoplanets." Annual Review of Astronomy and	Quite heavy used in my literature review to understand	Credible as it is located in the Annual Review of Astronomy and Astrophysics

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		Astrophysics 50.411 (2012): 2012.	concepts of how scientists identify planets by microlensing	
The assembling and usage of low-cost refractor telescopes as motivating experience in astronomy education	Research Report	<sup>1</sup> Iachel, Gustavo, et al. "The assembling and usage of low-cost refractor telescopes as motivating experience in astronomy education." Revista Brasileira de Ensino de Física 31 (2009): 4502-4508.	Quite heavy used in my methodology to understand how to use my telescope most effectively	Credible as it is a clear investigation carried out
Introduction to the physics and techniques of remote sensing	Research Report	<sup>1</sup> Elachi, Charles, and Jakob J. Van Zyl. Introduction to the physics and techniques of remote sensing. John Wiley & Sons, 2021.	Quite heavy used in my literature review to understand concepts of how scientists identify planets by remote sensing	Credible as from John Wiley and Sons publication and peer reviewed by physicists in various fields
Characterising the Potential for Planetary Habitability: A Study of the Temporal Evolution of Exoplanet Habitable Zones	Research Report	<sup>1</sup> Hogan, Jessica. Characterising the Potential for Planetary Habitability: A Study of the Temporal Evolution of Exoplanet Habitable Zones. No. EPSC2022-369. Copernicus Meetings, 2022.	Quite heavy used in my methodology to understand concepts of how scientists understand the characteristics of exoplanets	Credible as from the euoplanet science congress
The evolution of solar ultraviolet luminosity	Research Report	<sup>1</sup> Zahnle, Kevin J., and James CG Walker. "The evolution of solar ultraviolet luminosity." Reviews of Geophysics 20.2 (1982): 280-292.	Quite heavy used in my literature review to understand ultraviolet luminosity	Credible as from a peer reviewed geophysics report
Solar radiation pressure,	Research Report	<sup>1</sup> Jagannatha, Bindu. "Solar radiation pressure, drag and gravitational effects	Quite heavy used in my literature	Credible as a dissertation peer reviewed by the

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drag and gravitational effects on a dust particle in Earth orbit		on a dust particle in Earth orbit." (2012).	review to understand solar radiation, pressure and drag	director of research Victoria Coverstone
Holographic Optical Method for Exoplanet Spectroscopy (HOMES)	Research Report	<sup>1</sup> Ditto, Thomas D., et al. Holographic Optical Method for Exoplanet Spectroscopy (HOMES). No. HQ-E-DAA-TN41345. 2017.	Quite heavy used in my literature review to understand how HOMES works	Credible as published by the proceedings of the SPIE
Photometry with DSLR cameras	Research Report	<sup>1</sup> Hoot, John E. "Photometry with DSLR cameras." Society for Astronomical Sciences Annual Symposium. Vol. 26. 2007.	Heavy - used in my methodology to understand how a DSLR can be used to see the cosmos	Credible as it is in the Annual Review of Astronomy and Astrophysics
Photometry of the variable stars using CCD detectors. I. Photometric reduction	Research Report	<sup>1</sup> Parimucha, S., and M. Vanko. "Photometry of the variable stars using CCD detectors. I. Photometric reduction." Contributions of the Astronomical Observatory Skalnat Pleso 35 (2005): 35-44.	Heavy - used in my methodology to understand how a DSLR can be used to see variable stars	Credible as a peer reviewed report from the Astronomical Observatory
Eternity in low Earth orbit: icons on the International Space Station	Research Report	<sup>1</sup> Salmond, Wendy, Justin Walsh, and Alice Gorman. "Eternity in low Earth orbit: icons on the International Space Station." Religions 11.11 (2020): 611.	Quite heavy used in my literature review to understand orbits in space	Credible as an article peer reviewed and originally published by Chapman University
Control of Lagrange point orbits using solar sail propulsion	Research Report	<sup>1</sup> Bookless, John, and Colin McInnes. "Control of Lagrange point orbits using solar sail propulsion." Acta Astronautica 62.2-3 (2008): 159-176.	Heavy - used in my literature review to understand orbits in space	Credible as published in the peer reviewed journal of Guidance, Control and Dynamics
Overview of James Webb	Research Report	<sup>1</sup> Rieke, Marcia J., Douglas M. Kelly, and Scott D. Horner.	Quite heavy used in my literature	Credible as from peer reviewed journal Cryogenic

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Space Telescope and NIRCam's Role		"Overview of James Webb Space Telescope and NIRCam's Role." Cryogenic Optical Systems and Instruments XI. Vol. 5904. SPIE, 2005.	review to understand sensors used in the JWST to get the pictures	Optical Systems and Instruments
Scientific results from the orbiting astronomical observatory (OAO-2)	Datasets	<sup>1</sup> Code, Arthur D. "Scientific results from the orbiting astronomical observatory (OAO-2)." Scientific results from the orbiting astronomical observatory (OAO-2). Vol. 310. 1972.	Quite heavy used in my literature review to understand orbits of astronomical observatories in space	Credible as a peer reviewed report from the Astronomical Observatory
But what will it cost? The history of NASA cost estimating	Datasets	<sup>1</sup> Hamaker, Joseph W. "But what will it cost? The history of NASA cost estimating." Readings in Program Control 6103 (1994): 25.	Quite heavy used in my literature review to understand the budget NASA has	Credible as from analysis of NASA data publically available from the government of US
ARTEMIS science objectives	Books	<sup>1</sup> Sibeck, D. G., et al. "ARTEMIS science objectives." The ARTEMIS mission. Springer, New York, NY, 2011. 27-59.	Heavy - used in my literature review to understand the objectives of future space discovery	Credible as from popular peer reviewed book Springer
Instrumentation for the detection and characterization of exoplanets	Books	<sup>1</sup> Pepe, Francesco, David Ehrenreich, and Michael R. Meyer. "Instrumentation for the detection and characterization of exoplanets." Nature 513.7518 (2014): 358-366.	Quite heavy used in my literature review to understand instruments used to characterise exoplanets	Credible as from popular peer reviewed book Nature
A new view of early Greek astronomy	Books	<sup>1</sup> Goldstein, Bernard R., and Alan C. Bowen. "A new view of early Greek astronomy." Isis 74.3 (1983): 330-340.	Minimal as Greek astronomy wasn't the main focus of my essay	Credible as from a peer reviewed published book on Zodiac Calendars in the Dead Sea

New far infrared and millimetric telescopes for differential measurements with a large chopping angle in the sky	Books	<sup>1</sup> De Petris, Marco, Massimo Gervasi, and Fabrizio Liberati. "New far infrared and millimetric telescopes for differential measurements with a large chopping angle in the sky." <i>Applied optics</i> 28.10 (1989): 1785-1792.	Quite heavy used in my literature review to understand instruments used to see in the night sky	Credible as from popular peer reviewed book <i>Applied Optics</i>
Types of Telescopes	Books	<sup>1</sup> Kitchin, Christopher Robert. "Types of Telescopes." <i>Telescopes and Techniques</i> . Springer, New York, NY, 2013. 3-30.	Quite heavy used in my methodology to understand the different types of telescopes I could use	Credible as from popular peer reviewed book Springer
Mirrors for optical telescopes	Books	<sup>1</sup> Miroshnikov, Mikhail M., Sergey V. Ljubarsky, and Yuri P. Khimitch. "Mirrors for optical telescopes." <i>Optical Engineering</i> 31.4 (1992): 701-710.	Quite heavy used in my literature review to understand how mirrors are used in telescopes	Credible as from peer reviewed journal <i>Optical Engineering</i>
In the grip of the big telescope age	Books	<sup>1</sup> DeVorkin, David H. "In the grip of the big telescope age." <i>Experimental Astronomy</i> 25.1 (2009): 63-77.	Quite heavy used in my literature review to understand how scientists use big telescopes	Credible as from popular peer reviewed book <i>Experimental Astronomy</i>
The radial velocity method for the detection of exoplanets	Books	<sup>1</sup> Hatzes, Artie P. "The radial velocity method for the detection of exoplanets." <i>Methods of Detecting Exoplanets</i> . Springer, Cham, 2016. 3-86.	Quite heavy used in my literature review to understand the radial velocity method by which scientists detect exoplanets	Credible as from popular peer reviewed book Springer
The Andromeda Galaxy	Books	<sup>1</sup> Hodge, Paul. <i>The Andromeda Galaxy</i> . Vol. 176. Springer	Quite heavy used in my literature	Credible as from popular peer reviewed book

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		Science & Business Media, 2013.	review to understand the andromeda and other galaxies	Springer Science & Business Media
Space and atmospheric environments: from low earth orbits to deep space	Books	<sup>1</sup> Barth, Janet L. "Space and atmospheric environments: from low earth orbits to deep space." Protection of materials and structures from space environment. Springer, Dordrecht, 2004. 7-29.	Quite heavy used in my literature review to understand instruments used to characterise exoplanets	Credible as from popular peer reviewed book Springer
Recent developments in nanomaterial optical sensors	Books	<sup>1</sup> Shi, Jinjun, et al. "Recent developments in nanomaterial optical sensors." TrAC Trends in Analytical Chemistry 23.5 (2004): 351-360.	Quite heavy used in my literature review to understand very small optical sensors	Credible as from popular peer reviewed book TrAC
Constraint release in star/star blends and partial tube dilation in monodisperse star systems	Books	<sup>1</sup> Watanabe, Hiroshi, Toshiaki Sawada, and Yumi Matsumiya. "Constraint release in star/star blends and partial tube dilation in monodisperse star systems." Macromolecules 39.7 (2006): 2553-2561.	Quite heavy used in my literature review to understand how single star systems are dispersed	Credible as from peer reviewed journal Macromolecules
The Goldilocks Zone: Conditions Necessary for Extraterrestrial Life	Books	<sup>1</sup> La Bella, Laura. The Goldilocks Zone: Conditions Necessary for Extraterrestrial Life. The Rosen Publishing Group, Inc, 2015.	Quite heavy used in my literature review to understand the conditions necessary for exoplanets to exist	Credible as from publisher The Rosen Publishing Group, Inc
The distance to the Andromeda galaxy from	Books	<sup>1</sup> Vilardell, Francesc, et al. "The distance to the Andromeda galaxy from eclipsing binaries." Astronomy &	Quite heavy used in my literature review to understand	Credible as from popular peer reviewed book Astronomy and Astrophysics

eclipsing binaries		Astrophysics 509 (2010): A70.	distances in space	
Star complexes and associations in the Andromeda galaxy	Books	<sup>1</sup> Efremov, Yu N., G. R. Ivanov, and N. S. Nikolov. "Star complexes and associations in the Andromeda galaxy." <i>Astrophysics and space science</i> 135.1 (1987): 119-130.	Quite heavy used in my literature review to understand star complexes in the Andromeda galaxy	Credible as from popular peer reviewed book <i>Astrophysics and space science</i>
Ground-based photometry of space-based transit detections: photometric follow-up of the CoRoT mission	Books	<sup>1</sup> Deeg, H. J., et al. "Ground-based photometry of space-based transit detections: photometric follow-up of the CoRoT mission." <i>Astronomy &amp; Astrophysics</i> 506.1 (2009): 343-352.	Quite heavy used in my literature review to understand how transits are used by scientists	Credible as from popular peer reviewed book <i>Astronomy and Astrophysics</i>
Space exploration and environmental issues	Books	<sup>1</sup> Hartmann, William K. "Space exploration and environmental issues." <i>Environmental Ethics</i> 6.3 (1984): 227-239.	Quite heavy used in my literature review to understand issues in space exploration	Credible as from popular peer reviewed book <i>Environmental ethics</i>
The Space Telescope	Magazines	<sup>1</sup> Bahcall, John N., and Lyman Spitzer. "The Space Telescope." <i>Scientific American</i> , vol. 247, no. 1, 1982, pp. 40–51. JSTOR, <a href="http://www.jstor.org/stable/24966634">http://www.jstor.org/stable/24966634</a> . Accessed 12 Aug. 2022.	Quite heavy used in my literature review to understand what the main idea is of space based telescopes	Based in scholarly research although not peer reviewed still quite credible
The Reflector—The Telescope of the Future	Magazines	<sup>1</sup> Fath, Edward Arthur. "The Reflector—The Telescope of the Future." <i>Scientific American</i> , vol. 109, no. 2, 1913, pp. 30–30. JSTOR, <a href="http://www.jstor.org/">http://www.jstor.org/</a>	Quite heavy used in my literature review to understand reflector telescopes	Based in scholarly research although not peer reviewed still quite credible

		stable/26019959. Accessed 12 Aug. 2022.		
American Scientist – Astrophysics for the Amateur	Magazines	<sup>1</sup> White, Raymond E. American Scientist, vol. 75, no. 5, 1987, pp. 525–26. JSTOR, <a href="http://www.jstor.org/stable/27854803">http://www.jstor.org/stable/27854803</a> . Accessed 12 Aug. 2022.	Quite heavy used in my literature review to understand how astrophysics is used in astronomy	Based in scholarly research although not peer reviewed still quite credible
Dslr-quality photos on mobile devices with deep convolutional networks	Magazines	<sup>1</sup> Ignatov, Andrey, et al. "Dslr-quality photos on mobile devices with deep convolutional networks." Proceedings of the IEEE International Conference on Computer Vision. 2017.	Quite heavy used in my methodology to understand how DSLR cameras can take the best photos of space	Credible as from the international conference on computer vision
Scientific discovery with the James Webb space telescope	Magazines	<sup>1</sup> Kalirai, Jason. "Scientific discovery with the James Webb space telescope." <i>Contemporary Physics</i> 59.3 (2018): 251-290.	Quite heavy used in my literature review to understand how the James Webb takes such stunning photos	Quite credible from peer reviewed book Contemporary Physics
Free-space laser communication system with rapid acquisition based on astronomical telescopes	Magazines	<sup>1</sup> Wang, Jianmin, et al. "Free-space laser communication system with rapid acquisition based on astronomical telescopes." <i>Optics Express</i> 23.16 (2015): 20655-20667.	Quite heavy used in my literature review to understand how telescopes communicate with each other	Credible from biweekly peer reviewed journal Optics Express
Effect of orbital shadow at an Earth-Moon Lagrange point on relay	Magazines	<sup>1</sup> Tang, Yuhua, et al. "Effect of orbital shadow at an Earth-Moon Lagrange point on relay communication mission." <i>Science China Information Sciences</i> 60.11 (2017): 1-10.	Quite heavy used in my literature review to understand Lagrange points and the main disadvantages	Credible from peer reviewed book Science China Information Sciences by experts in the field

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communication mission				
Some new astronomical instruments	Astronomical Society Notices	<sup>1</sup> Schlesinger, Frank. "SOME NEW ASTRONOMICAL INSTRUMENTS." Publications of the Astronomical Society of the Pacific, vol. 14, no. 84, 1902, pp. 87–95. JSTOR, <a href="http://www.jstor.org/stable/40668241">http://www.jstor.org/stable/40668241</a> . Accessed 12 Aug. 2022.	Quite heavy used in my literature review to understand how new astronomical instruments are constructed	Credible as from popular monthly peer reviewed publication of the Astronomical Society of the Pacific
What Happens to Am Stars After They Leave the Main Sequence?	Astronomical Society Notices	<sup>1</sup> Abt, Helmut A. "What Happens to Am Stars After They Leave the Main Sequence?" Publications of the Astronomical Society of the Pacific, vol. 129, no. 974, 2017, pp. 1–4. JSTOR, <a href="https://www.jstor.org/stable/26660086">https://www.jstor.org/stable/26660086</a> . Accessed 12 Aug. 2022.	Quite heavy used in my literature review to understand the life cycle of stars	Credible as from popular monthly peer reviewed publication of the Astronomical Society of the Pacific
On the light of the Sun, Moon, Jupiter, and Venus	Astronomical Society Notices	<sup>1</sup> Bond, G. P. "On the light of the Sun, Moon, Jupiter, and Venus." Monthly Notices of the Royal Astronomical Society 21 (1861): 197.	Quite heavy used in my literature review to understand how we can use the moon to take photos of space	Credible as from popular monthly peer reviewed publication of the Astronomical Society of the Pacific
Impact of radial migration on stellar and gas radial metallicity distribution	Astronomical Society Notices	<sup>1</sup> Grand, Robert JJ, Daisuke Kawata, and Mark Cropper. "Impact of radial migration on stellar and gas radial metallicity distribution." Monthly Notices of the Royal Astronomical Society 447.4 (2015): 4018-4027.	Quite heavy used in my literature review to understand how scientists determine metal distribution of planets	Credible as a astronomical society notice which are rigorously peer reviewed by the RAS

The Oxyometer	Astronomical Society Notices	<sup>1</sup> Baker, Ashley D., Cullen H. Blake, and Sam Halverson. "The Oxyometer." Publications of the Astronomical Society of the Pacific 131.1000 (2019): 1-22.	Quite heavy used in my literature review to understand how the Oxyometer works	Credible as from popular monthly peer reviewed publication of the Astronomical Society of the Pacific
The Oxyometer: A Novel Instrument Concept for Characterizing Exoplanet Atmospheres	Astronomical Society Notices	<sup>1</sup> Baker, Ashley D., Cullen H. Blake, and Sam Halverson. "The Oxyometer: A Novel Instrument Concept for Characterizing Exoplanet Atmospheres." Publications of the Astronomical Society of the Pacific 131.1000 (2019): 064402.	Quite heavy used in my literature review to understand how the Oxyometer is used to detect exoplanets	Credible as from popular monthly peer reviewed publication of the Astronomical Society of the Pacific
Searching for exoplanets using artificial intelligence	Astronomical Society Notices	<sup>1</sup> Pearson, Kyle A., Leon Palafox, and Caitlin A. Griffith. "Searching for exoplanets using artificial intelligence." Monthly Notices of the Royal Astronomical Society 474.1 (2018): 478-491.	Quite heavy used in my literature review to understand how computers can be used to categorise exoplanets	Credible as a astronomical society notice which are rigorously peer reviewed by the RAS
On the formation of planets in binary star systems	Astronomical Society Notices	<sup>1</sup> Heppenheimer, T. A. "On the formation of planets in binary star systems." Astronomy and Astrophysics 65 (1978): 421-426.	Quite heavy used in my literature review to understand how binary star systems form and see why they are the most common in the universe	Credible as from popular peer reviewed book Astronomy and Astrophysics
Vega-type systems	Dissertation	<sup>1</sup> Artymowicz, Pawel. "Vega-type systems." The Role of Dust in the Formation of Stars (1996): 137-148.	Quite heavy used in my methodology to understand the Vega star	Credible as from a dissertation peer reviewed by professors of University College of London



			system I saw in my pictures	
Budget documents, strategic plans, and performance reports	Space Agency Official Documents	<a href="https://www.nasa.gov/news/budget/index.html">https://www.nasa.gov/news/budget/index.html</a> Last accessed 15/08/2022	Quite heavy used in my literature review to understand the main setback in finding exoplanets	Credible as legally provided by NASA from the government of USA
Hipparchus on the Distances of the Sun and Moon	Archives	<sup>1</sup> Toomer, Gerald J. "Hipparchus on the Distances of the Sun and Moon." Archive for History of Exact Sciences (1974): 126-142.	Very minimal – as I am focussing more on how telescopes are used to find exoplanets rather than the history of how we found the distances between the sun and the moon	Credible as an archive of sources from peer reviewed academic journal History of Exact Sciences
The NASA Exoplanet Archive: Data and Tools for Exoplanet Research	Archives	<sup>1</sup> Akesson, R. L., et al. "The NASA Exoplanet Archive: Data and Tools for Exoplanet Research." Publications of the Astronomical Society of the Pacific, vol. 125, no. 930, 2013, pp. 989–99. JSTOR, <a href="https://doi.org/10.1086/672273">https://doi.org/10.1086/672273</a> . Accessed 12 Aug. 2022.	Quite heavy used in my literature review to see the data we have for exoplanets at this current stage in time	Credible as an archive from popular monthly peer reviewed publication of the Astronomical Society of the Pacific
The Research and Analysis of Parallax Error Decrease in Astronomical Navigation Positioning	Press	<sup>1</sup> Wu, Jianhua, et al. "The Research and Analysis of Parallax Error Decrease in Astronomical Navigation Positioning." 2013 the International Conference on Remote Sensing, Environment and Transportation	Minimal - used in my literature review to understand how we overcome parallax	Credible as Peer-reviewed statement in all major STM disciplines

		Engineering (RSETTE 2013). Atlantis Press, 2013.		
The development of Newtonian calculus in Britain 1700-1800	Press	<sup>1</sup> Guicciardini, Niccolò. The development of Newtonian calculus in Britain 1700-1800. Cambridge: Cambridge University Press, 1989.	Very minimal - used in my literature review to understand Newton invented a way we can use maths to represent space but since it was not the main focus I did not talk a lot about it.	Credible as from extensively peer reviewed press from Cambridge University
Jupiter: the planet, satellites and magnetosphere	Press	<sup>1</sup> Bagenal, Fran, et al., eds. Jupiter: the planet, satellites and magnetosphere. Vol. 1. Cambridge University Press, 2007.	Quite heavy used in my literature review to understand how we can identify magnetic fields of distant planets by using Jupiter as an example	Credible as from extensively peer reviewed press from Cambridge University
Picturing the cosmos: Hubble Space Telescope images	Press	<sup>1</sup> Kessler, Elizabeth A. Picturing the cosmos: Hubble Space Telescope images and the astronomical sublime. Minneapolis: University of Minnesota Press, 2012.	Quite heavy used in my literature review to see how the Hubble space telescope take such pictures	Credible as from extensively peer reviewed press from the University of Minnesota Press
The Cambridge guide to the constellations	Press	<sup>1</sup> Bakich, Michael E. The Cambridge guide to the constellations. Cambridge University Press, 1995.	Quite heavy used in my methodology to identify the star systems I have taken photos of	Credible as from extensively peer reviewed press from Cambridge University

The James Webb space telescope	Press	<sup>1</sup> Gardner, Jonathan P., et al. "The james webb space telescope." Space Science Reviews 123.4 (2006): 485-606.	Quite heavy used in my literature review to understand how the James Webb creates images	Potential bias as from a review from Space Science reviews
Feature selection using principal feature analysis	Multimedia Content	<sup>1</sup> Lu, Yijuan, et al. "Feature selection using principal feature analysis." Proceedings of the 15th ACM international conference on Multimedia. 2007.	Quite heavy used in my literature review to understand how photos are layered on top of each other to create a better overall photo	Credible as from the international conference of multimedia
Populations of planets in multiple star systems	Review Chapter	<sup>1</sup> Martin, David V. "Populations of planets in multiple star systems." arXiv preprint arXiv:1802.08693 (2018).	Quite heavy used in my literature review to understand the distribution of different star systems	Credible as from peer reviewed journal
The Hipparcos Pleiades parallax error is also a proper motion error	Abstract from Hipparcos catalog	<sup>1</sup> Makarov, Valeri V. "The Hipparcos Pleiades parallax error is also a proper motion error." arXiv preprint arXiv:2207.12975 (2022).	Minimal but used in my literature review to understand how a simple error creates such variation in data we received	Credible as from peer reviewed journal article
Panic! At the Disks: First Rest-frame Optical Observations of Galaxy Structure at $z > 3$ with JWST in the SMACS 0723 Field	Writings of research investigation	<sup>1</sup> Ferreira, Leonardo, et al. "Panic! At the Disks: First Rest-frame Optical Observations of Galaxy Structure at $z > 3$ with JWST in the SMACS 0723 Field." arXiv preprint arXiv:2207.09428 (2022).	Minimal but used in my literature review to understand how rest frames are used to enhance images on the James Webb	Credible as from peer reviewed writing research investigation

**Candidate number**

**Candidate's full name**

Dhruva Teja Turaga

Unscrambling the lensed galaxies in JWST images behind SMACS0723	Open Access astrophysical journal letter	<sup>1</sup> Pascale, Massimo, et al. "Unscrambling the lensed galaxies in JWST images behind SMACS0723." arXiv preprint arXiv:2207.07102 (2022).	Quite heavy used in my literature review to understand how we can see lensed galaxies	Credible as from peer reviewed open access journal letter
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