Twinkle - Programme Updates

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Abstract

Twinkle is one of the first in a series of innovative science satellites managed and operated by Blue Skies Space Ltd. The satellite design is based on a high-heritage Airbus platform, with a spectrometer designed by ABB Canada. The spacecraft will carry a 0.45 m telescope and a spectrometer that covers wavelengths from 0.5–4.5 μm simultaneously. Placed in a thermally-stable, sun-synchronous, low-Earth orbit, the mission will operate for seven years and conduct large-scale survey programs. The first three years will focus on both Solar System and Extrasolar targets. This paper presents the satellite's updated design, and key science themes developed by the Twinkle surveys' members.

1. INTRODUCTION

High-performance scientific satellites have been until recently the exclusive domain of government-funded agencies. While the role of agencies is critical for advancing science and technical innovation, scientists worldwide have expressed their desire to see flagship missions complemented by less ambitious, but more cost-effective and frequently launched satellites. To address this challenge, Blue Skies Space Ltd (BSSL) is developing a new class of small and sustainable science satellites that leverages recent innovations in the commercial space sector. To fund the construction and operation of its satellites, BSSL has implemented a commercial, service-based model, where scientists can join multi-year collaborative surveys at a fraction of the cost of a satellite (1).

The first two astrophysical satellites in the fleet of space observatories being developed by BSSL, are *Twinkle* (2; 3; 4; 5; 6) and *Mauve*.

In this paper we focus on *Twinkle*, highlighting the technical and programmatic updates that have occurred since the publication of previous papers outlining the mission (2; 6). Additionally, we summarise some of the key science interests of the current members of *Twinkle*'s extrasolar survey.

2. DESIGN UPDATES

The *Twinkle*'s design has been developed through continued activities with with Airbus (platform provider) and ABB Canada (spectrometer provider). *Twinkle* will sit in a thermally-stable, sun-synchronous, low-Earth orbit. The platform will carry a 0.45 m telescope and a spectrometer which will provide simultaneous wavelength coverage from 0.5–4.5 μm. This paper will outline some of the key design developments, most notably the platform selection.

2.1 Platform

BSSL and Airbus teams have identified the Airbus *Arrow* platform to be an optimal solution for *Twinkle*'s needs. The *Arrow* platform is a modified OneWeb platform that, subject to final engineering assessment, will offer schedule and performance improvements to the *Twinkle* satellite. Recent engineering studies have confirmed the technical suitability of this platform for deep space observations and detailed work is being carried out to finalise the thermo-mechanical accommodation of the *Twinkle* payload.

Among the advantages offered by the *Arrow*, there are the rapid build schedule offered by the production line methodology and orbit selection. Being the *Arrow* platform less massive, it supports significant delta-V capabilities allowing for the

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Space Telescopes and Instrumentation 2024: Optical, Infrared, and Millimeter Wave, edited by Laura E. Coyle, Shuji Matsuura, Marshall D. Perrin, Proc. of SPIE Vol. 13092, 1309213 · © 2024 SPIE · 0277-786X · doi: 10.1117/12.3018791

orbit altitude to be raised from an insert orbit to up to 1200km. This possibility has a positive impact for the scientific observations as the obstruction across the Field of Regard (FoR) caused by the Earth will be significantly reduced. The *Arrow* platform is expected to be highly stable and repeatable, lending itself well to long baseline observations across a broad Field of Regard.

Being *Twinkle* a satellite conceived to provide infrared data, the thermal design remains the most significant challenge. However, the possibility of operating the platform at a higher altitude, would reduce the impact of the Earth's thermal radiation. Further studies to optimise the accommodation of the cryocooler and of the thermal design are ongoing. Additional details will be available to share with the community after the summer while the overall platform performances remain in line or slightly improved compared to previous designs (2; 6).

Figure 1: Artistic render of the Airbus *Arrow* platform configured for the Twinkle mission. Image credit: Airbus

2.2 Payload

The spectrometer designed by ABB Canada adopts a prism as diffracting element. The selection of the optical parts was recently completed: this represents a critical milestone for the spectrometer design and allows for the native resolution of the instrument to be well understood. We refer explicitly to the native resolving power of the instrument in the plots provided in this document. Concurrent engineering will need to take place with the spacecraft prime but this major milestone of optical parts selection allows for the scientific performance analysis of *Twinkle* to be refined in the months to come, with specific resolving powers now identified across the two channels.

BSSL continues to develop *Twinkle* data pipelines alongside the ongoing design efforts to assist the Survey Science Teams in making more realistic scientific simulations and survey plans. This analysis will also soon include the impact of pointing stability and other potential sources of systematics.

3. TARGET AVAILABILITY

The new Airbus Arrow platform will allow Twinkle to operate in an approximately 1200km, sun-synchronous orbit, with a 0600 LTAN. We have compared the Field of Regard (FOR) enabled by this orbit to the FOR of a previously considered platform operating at a lower altitude, i.e. 700km (see Fig. 4). The FOR over the course of a year for the two orbits were modelled using the same exclusion angles for the Earth limb, Sun and Moon. The comparison was done using a new BSSL orbital tool which includes the python package Skyfield (7) developed to monitor orbit propagation of satellites, as well as tracking the position of the Sun, Earth, and Moon. This tool is capable of calculating the angle between the target the Earth limb, Sun and other celestial bodies, and propagates the satellite using the SGP4 propagator.

Our results show that at 1200km altitude, the median time a target is observable increases by ~ 150hr/yr compared to 700km, with some targets having an increase in accessible hours of 242hr/yr. In addition, we have longer continuous observations for targets that can be obstructed by the Earth: the median time a target is observable with no obstruction increases by ~ 35%, with the maximum almost doubling.

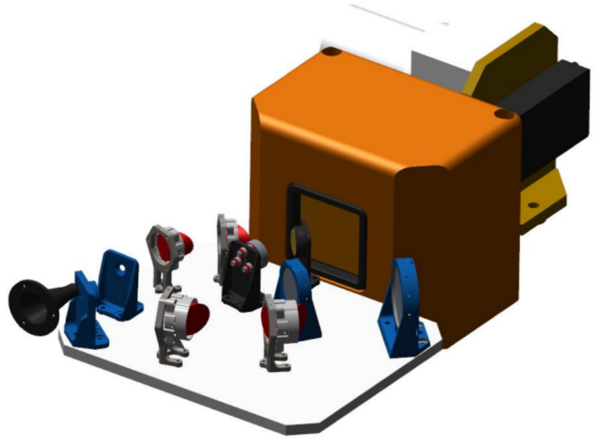
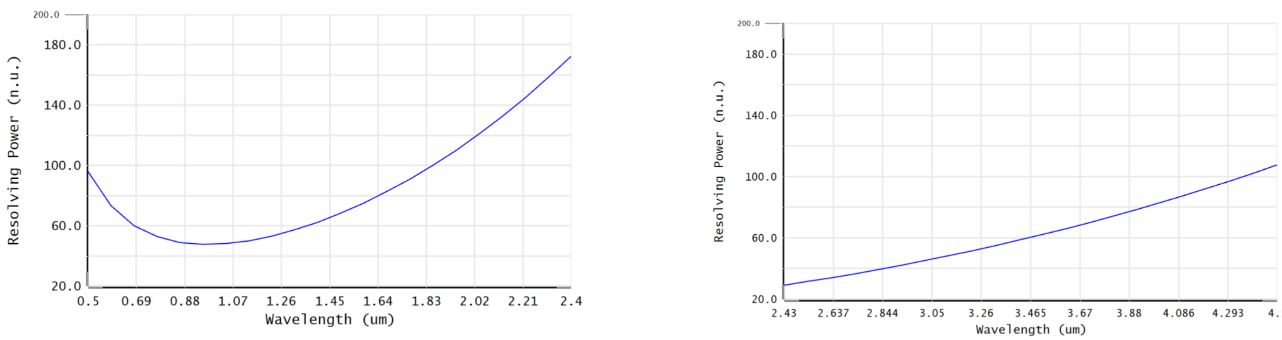


Figure 2: Optical bench configuration of the Twinkle spectrometer. Image credit: ABB



(a) Channel 0.

(b) Channel 1.

Figure 3: Native resolving powers of the two spectrometer channels. Image credit: ABB

4. SCIENCE WITH *TWINKLE*

While Blue Skies Space is responsible for the satellite, the data analysis tools and facilitating the survey planning process, researchers who join the survey program will decide the survey's scientific objectives and observational strategy. Prior to launch, these members, known as the *Survey Science Team*, have been tasked with delivering a comprehensive and scientifically optimised observational plan and list of targets. This plan is currently being consolidated and will be confirmed closer to launch.

During the first three years of operations, two large survey programmes will be implemented. The first of these will focus on extrasolar targets (5), while the second will be dedicated to studying objects within our own Solar System (3; 4). Each survey will have thousands of hours of telescope time, allowing for structured population-level studies to be undertaken. By allowing scientists to dedicate large amounts of time to individual science cases, Twinkle will enable researchers to answer fundamental questions about the formation and evolution of stars and planetary systems. Here, we briefly list some of the science cases currently being considered by the Twinkle Survey Science Team.

4.1 Extrasolar Survey

Twinkle's ability to provide simultaneous spectroscopic coverage between 0.5 and 4.5 μm facilitates scientific investigations into a wide variety of extrasolar objects. As such, Twinkle will provide high-quality visible and infrared spectroscopic characterisation of hundreds of bright exoplanets, stars and protoplanetary disks. To prepare the science plans and observational strategy, members of the Twinkle extrasolar survey have formed 6 working groups with 11 core science cases (see table 1) already well consolidated.

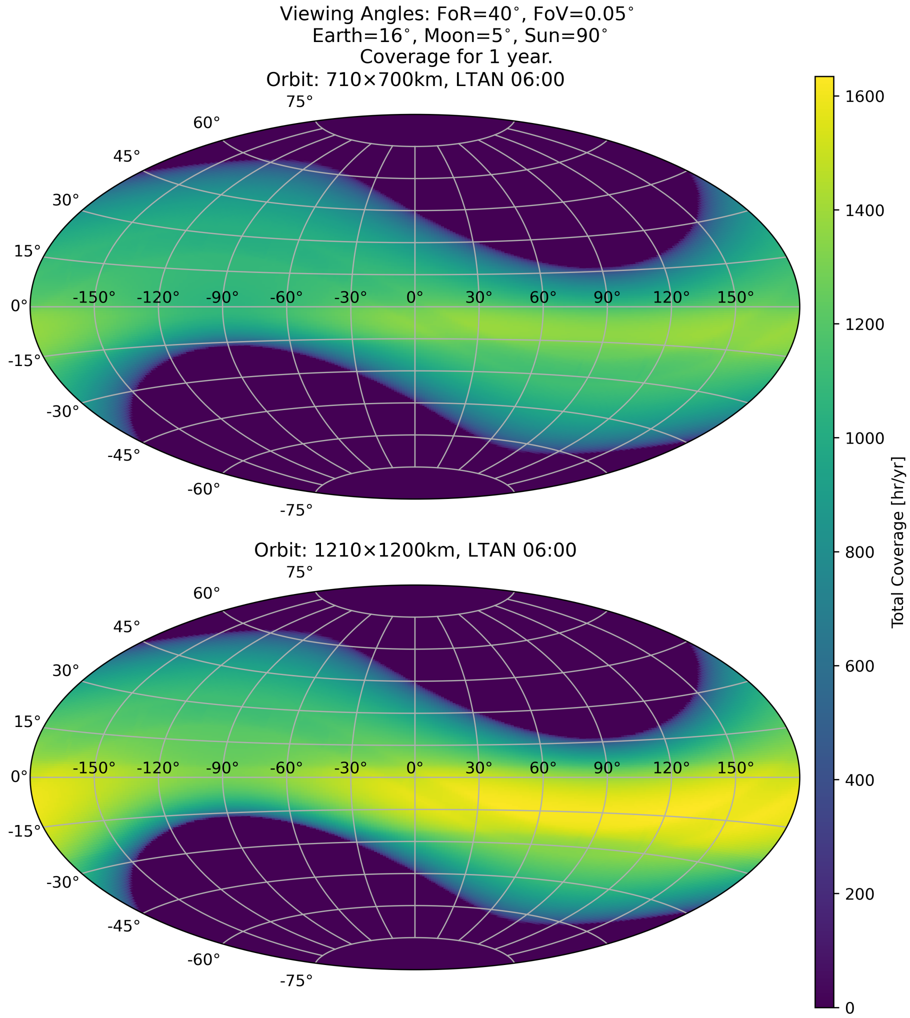


Figure 4: FOR of Twinkle's previously considered orbit (top, 700km), compared to the new orbit (bottom, 1200km), showing the total time each portion of the sky is accessible over the course of a year.

The Extrasolar Survey Science Team currently includes contributions from 32 scientists based in 11 institutes. These include Cardiff University, Commissariat à l'énergie atomique et aux énergies alternatives (CEA), Ludwig-Maximilians-Universität München, Memorial University of Newfoundland, Nanjing University, National Tsing Hua University, The Ohio State University, University of Central Lancashire, University of Delaware, University of Southern Queensland, and Vanderbilt University.

4.2 Synergies with other Facilities

The utilization of both ground and space-based telescopes, pre and post-launch has been identified as an integral component of the *Twinkle* Survey strategy. Combining data from *Twinkle* with other facilities, through a "multi-wavelength astronomy" approach will provide a more detailed understanding of the properties and behaviour of targets by expanding Twinkle's wavelength range and resolution. Therefore, while Twinkle will generate state-of-the-art datasets, it forms part of a more significant endeavour to investigate targets. Pre-launch, observations from other facilities can help refine the ephemerides of survey targets and conduct initial characterisation, optimizing the observational programme and contributing to the scheduling of targets (8; 9; 10). Post-launch, ground and space-based telescopes can be utilised to conduct simultaneous observations.

Ground-Based Telescopes present the easiest option for scheduling both pre- and post-launch observations. Current survey members have identified 8 ground-based telescopes they have access to in the northern and southern hemispheres

Table 1: Survey working groups and associated science themes considered by the Extrasolar Survey Science Team.

Working Group	**Science Themes**
Stellar & Sub-Stellar	Stellar characterisation Brown dwarf characterisation Spectroscopic survey of flares on nearby M-dwarfs
Protoplanetary Disks	Observations of polycyclic aromatic hydrocarbons (PAHs) in the atmosphere of protoplanetary disks and exoplanets Spectroscopy of externally irradiated protoplanetary disks
Hot Gas Giants	Characterising a population of sub-Saturn atmospheres Legacy survey of minor atmospheric species with Twinkle Atmospheric variability of exoplanets over stellar cycles
Cool Gas Giants	Characterising a population of cool gaseous planet atmospheres
Super-Earths & Sub-Neptunes	Biosignature detection in super-Earths and sub-Neptunes
Transit Timing Variations	Measuring transit timing variations

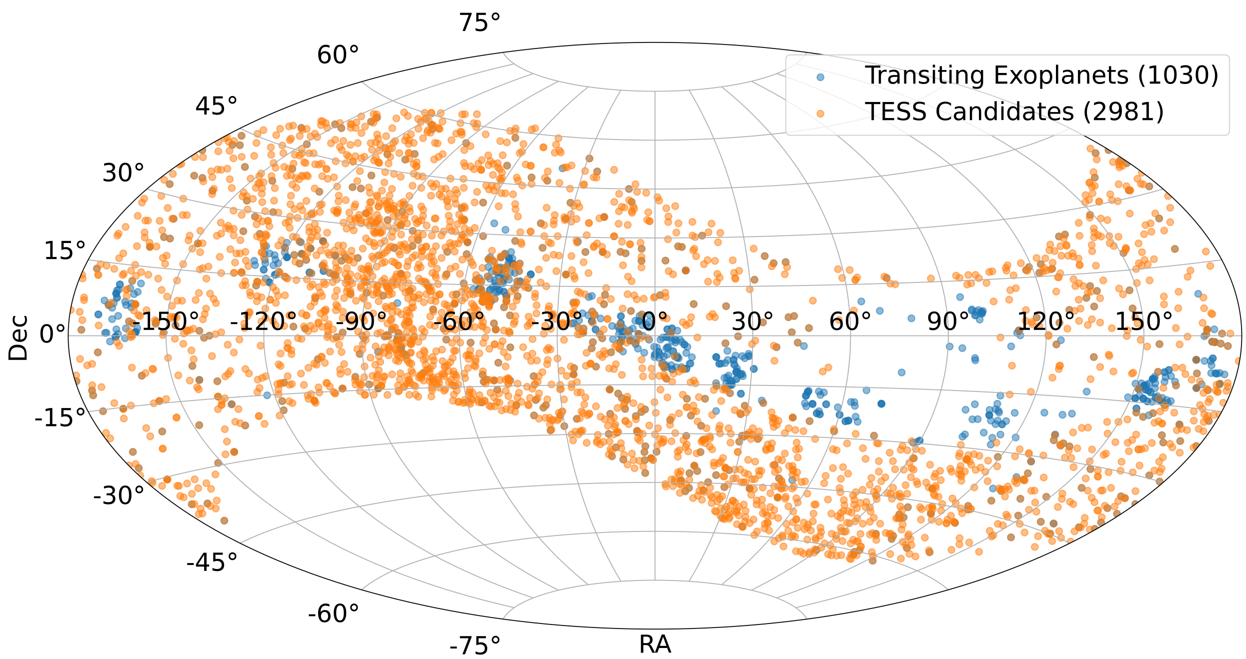


Figure 5: Twinkle's Field of Regard (FoR) showing the 1030 currently-known transiting exoplanets (blue), and the 2981 planet candidates from TESS (orange)

to engage in this effort. *Twinkle*'s low-resolution spectroscopy over a broad wavelength range from space will complement the high-resolution spectroscopy being conducted from the ground (11; 12; 13; 14).

Space-Based Telescopes. Flagship agency-led telescopes, such as NASA/ESA/CSA *James Webb Space Telescope* and ESA *Ariel*, will have significant overlap in both operational timelines and wavelength ranges with *Twinkle*, as explored in our 2022 SPIE paper (2). However, high-risk, high-gain pilot programs, which are very difficult to carry out with over-subscribed facilities (15), can easily be done with *Twinkle*. The innovative approach to science data, as enabled by

BSSL, allows to support understudied science cases and facilitate serendipitous discoveries.

Twinkle's spectro-photometric data extending to the Mid-IR will also be useful to refine planetary, stellar and orbital parameters and search for transit time and duration variations (TTVs and TDVs) in support of missions such as ESA *PLATO* and NASA *TESS*.

Future facilities being developed by Blue Skies Space, such as *Mauve*, an ultraviolet and visible wavelength space telescope will also present interesting opportunities for simultaneous observations and expanded wavelength coverage that captures ultraviolet, visible and infrared data.

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