Final Programme

Day 1 – Saturday, 7th May 2022

BST	EDT	PDT	Section	Title	Description	Speaker
11:00	06:00	03:00		Welcome		Dr Paul A. Daniels *President,* *Federation of Astronomical Societies, UK* 
11:05	06:05	03:05	Overview	An Introduction to Megaconstellations	We have the sense of being at a point of dramatic change, whether for good or for ill. How did we get here, and where might we be going next? This opening talk will set the challenge of megaconstellations in a historical perspective, and also in the broader context of the idea of space environmentalism. We will briefly lay out the themes which other speakers will explore.	Prof Andy Lawrence *Regius Professor of Astronomy,* *University of Edinburgh,* *UK* 
11:30	06:30	03:30	Operators	SpaceX Satellites and the Night Sky	Since the initial launch of SpaceX Starlink satellites in 2019, SpaceX has collaborated with astronomers in the US and internationally to assess the impact of Starlink on astronomical observations, and to identify, develop, field and test mitigations. The goal of Starlink is to provide high-speed, low-latency broadband connectivity across the globe, including to locations where internet has traditionally been too expensive, unreliable, or entirely unavailable. SpaceX firmly believes in the importance of a natural night sky for all of us to enjoy, which is why we have been working with leading astronomers around the world to better understand the specifics of their observations and engineering changes we can make to reduce satellite brightness. With both space sustainability and mitigations for astronomy in mind, we have pushed the state-of-the-art in key technology areas to address this new engineering challenge, and are striving to be the world's most open and transparent satellite operator. SpaceX will present an overview of Starlink satellite operations and the work we've done to minimize the impact on astronomy.	David Goldstein *SpaceX Principal Engineer* *California, USA* 
11:55	06:55	03:55		Responsible Constellations	Leadership in Responsible Space must encompass the adoption of responsible design and operational practices alongside market access incentives. Recent years have seen the introduction of a new era of commercial space activity, driven by advancements in technology, increases in private investment, and reductions in satellite manufacturing and launch costs. Small satellites are being launched in unprecedented numbers, and proposals for large, low-Earth-orbit (LEO) constellations are a reality. This new era of space activity is expanding space-based global communications, remote sensing, and a host of novel services that promise new opportunities for economic development, global education, rural healthcare, location-based services, and advancements in environmental science. For the global space economy to flourish and to realize these opportunities, we must preserve a safe operating environment.	Maurizio Vanotti *Vice President,* *Space Infrastructure & Partnerships, UK* 
12:20	07:20	04:20		40 Minute Lunch/Breakfast		
13:00	08:00	05:00	Challenges	Space Debris environment	Space debris environment: mitigation and its evolution with large constellations	Dr Hélène Ma *SST Test and Validation Engineer,* *RHEA System GmbH for ESA/ESOC* 
13:25	08:25	05:25		Flying Through Polluted Skies	The impact of space debris around our planet is not just felt by astronomers on Earth but is an ever-present challenge of daily life for those charged with keeping the satellites in the skies above our heads safe, one which will only be magnified by the advent of megaconstellations. Thomas will share his experience of what it's like piloting a spacecraft through these fields of junk, how we keep our satellites safe, what the impact is on the science missions we rely on and how space weather adds yet another element of difficulty to an already demanding situation.	Dr Thomas Ormston *Sentinel-1 Deputy Spacecraft Operations Manager, ESA* 
13:50	08:50	05:50		Space Traffic Control	There is an increasing need for effective Space Traffic Control in order to manage the growing numbers of objects in Earth orbit, both active satellites and space debris. The talk will suggest measures that can be taken by satellite operators, licensing authorities, and companies which are developing space surveillance networks in order to deliver a sustainable environment for future space operations.	Stuart Eves *Director, SJE Space Ltd, UK* 
14:15	09:15	06:15		Q&A		Dr Robert Massey & Panel
14:35	09:35	06:35		15 Minute Break		
14:50	09:50	06:50	Challenges	The environmental consequences of industrializing Earth orbits	Low Earth Orbit is being developed rapidly and unsustainably. While such development is increasingly being recognized as a major stressor on the satellite operational environment, it also has direct implications for environments on Earth. For example, the construction and maintenance of large satellite constellations will affect Earth's atmosphere through rocket exhaust products. The steady, high rate of satellite re-entries, driven by the short operational lifetimes of satellites in large constellations, will further cause significant elemental abundance loading of the upper atmosphere, far exceeding natural abundance loading from meteoroids for some important materials. This talk addresses several of these issues and their consequences, highlighting a growing collective action problem that connects the Earth and orbital space environments.	Prof Aaron C. Boley *Canada Research Chair in Planetary Astronomy* *Associate Professor at University of British Columbia, Canada* *Co-director of the Outer Space Institute* 
15:15	10:15	07:15		Satellite light pollution: an emerging threat to global night skies	The human use of the orbital space near the Earth entered a new era in May 2019 with the launch of the first objects in the 'Starlink' satellite constellation by the private commercial space company, SpaceX. In the three years since, the number of functional satellites in orbit has more than doubled, raising the specter of the rapid proliferation of new space debris. Various companies have proposed the launch of hundreds of thousands of new objects into low-Earth orbit in the remaining years of the 2020s. While astronomers have to date been largely concerned with the effects of bright streaks or trails of light in their images, I will present evidence of another kind of "light pollution" associated with these objects, which is their contribution to the diffuse brightness of the night sky. I will explain the theory underpinning models of this effect; their sensitivity to different input parameters; and what they imply about satellite impacts to overall night sky brightness at this point in time. Finally, I will discuss predictions of the models that may help ultimately mitigate effects of satellites and space debris on astronomy.	Dr John C. Barentine *Principal Consultant,* *Dark Sky Consulting LLC,* *Arizona, USA* 
15:40	10:40	07:40	Challenges	The impact of megaconstellations on heritage and Indigenous relationships to the night sky.	Humans have long gazed up in wonder at the starry night sky. Across the world, and throughout time, people have found meaning in the predictable patterns of celestial objects visible in a clear, dark night sky. With the advent of widespread artificial light at night, skyglow and light pollution have gradually decreased the visibility of the stars and the Milky Way, particularly in urban locales. Yet in remote areas, it is still possible to experience relatively pristine skies. However, the advent of large satellite constellations stands to irrevocably alter the night sky worldwide, permanently altering our view of the universe and our relationship with it. Indigenous Communities have had relationships with the night sky since time immemorial. Elders and knowledge holders have protected these relationships through ceremonies and tellings. These relationships are now in harm as the night sky changes with each added object that masks the original tellings. *As respect for their culture, we have agreed with Doug and Juan-Carlos that we will <u>not</u> record this part of the talk and, in consequence, it will not form part of the post-webinar YouTube video.*	Jessica Heim *Cultural Astronomer* *PhD student, University of Southern Queensland, Australia*  Doug Sinclair *Ojibways of Onigaming, Health counselor, Knowledge keeper and ceremonialist, Canada* Dr Juan-Carlos Chavez *Research Investigator,* *Blue Marble Space Institute of Science, Seattle,USA and Indigenous of Sonora Desert inter-tribal knowledge messenger* 
16:10	11:10	08:10		10 Minute Break		

BST	EDT	PDT	Section	Title	Description	Speaker
16:20	11:20	08:20	Challenges	The Challenge of Megaconstellations in an Environmental Context	In the 55 years since the Outer Space Treaty came into existence there has been substantial growth in the number of space objects, and the ways in which space has been utilised to improve life on Earth. Earth orbit has become a fundamental infrastructure for human life on Earth. Megaconstellations are continuation of these developments. This has been facilitated by space law, but Megaconstellations in particular and the general proliferation of space objects in Earth orbit present a number of challenges. There are legal challenges around, licencing and liability, regulation and control but there are also broader environmental and society challenges. This talk will examine these challenges.	Dr Thomas Cheney *Lecturer of Space Governance, AstrobiologyOU,* *Open University, UK* 
16:45	11:45	08:45		Overcoming Legal Challenges to a Sustainable Space Future	The emergence of mega-constellations ignited a latent conflict between the growth of commercial satellites and the preservation of a sustainable space in Earth's orbital environment. Over the last few years, the resulting perturbations became manifest within the space legal paradigm. On one hand, government seeks to encourage growth in the commercial space sector through "streamlined regulations." Elsewhere, after years of deliberations, government recognizes the need to more forcefully mitigation space debris and ensure effective SSA and STM. Recently, threats to space access by astronomers, scientists, and anyone who appreciates an unencumbered night sky imposed a real need to manage Earth's orbital environment. Given these diverse interests, there exist real challenges to efficient and equitable regulation of space. Unless overcome, these challenges may overwhelm and cause Earth to become planet-locked. This presentation will identify many of these challenges; address those that are reasonable and effective, and those that are not; propose a regulatory lens by which to view the future; and, offer solutions to a viable and sustainable space future.	Charles L. Mudd Jr. *Principal,* *Mudd Law, Illinois, USA* *Adjunct Professor (Space Law),* *Quinnipiac University, USA* 
17:10	12:10	09:10		Q&A		Dr Robert Massey & Panel
17:40	12:40	09:40		Close of Day		Dr Paul A. Daniels

Day 2 – Sunday, 8th May 2022

BST	EDT	PDT	Section	Title	Description	Speaker
11:10	06:10	03:10		Welcome		Dr Paul A. Daniels *(see Day 1, 11:00 BST above)*
11:15	06:15	03:15	Challenges	The Megaconstellation Geometry: what do we see and when?	With many thousands of Megaconstellation satellites in orbit, hundreds or even thousands of them will be in the sky above an observer on Earth. We will quantify this, and discuss which of those are visible and when depending on the time of the night, the season, the latitude, *etc*. We will also see the implications for naked-eye observers.	Dr Olivier R. Hainaut *Full Astronomer,* *End-to-End Operations Scientist,* *ESO, Germany* 
11:40	06:40	03:40		Photometric Characterization of Mega-Constellation Satellites In All Geometries	The apparent brightness of a satellite in Earth orbit depends on many factors, paramount of which is the relative geometry to the Sun and the observer. With the *Pomenis LEO Satellite Mega-Constellation Survey* we have made over 10,000 separate photometric measurements of Starlink and OneWeb satellites. Our survey observes satellites across a broad range of geometries encompassing the entire hemispherical sky. Plotting the measurements across the sky shows the reflection pattern characteristic to each satellite model and reveals where the satellites reflect more or less light. With these sky plots we show what astronomers can expect with regards to apparent satellite brightness and how they may avoid the brightest and most impactful reflection geometries on the sky.	Harrison Krantz *PhD Candidate,* *University of Arizona Steward Observatory, Arizona, USA* 
12:05	07:05	04:05		40 Minute Lunch/Breakfast		
12:45	07:45	04:45	Challenges	Quantifying the impact on optical observations	Using detailed simulations, we evaluate and quantify the impact of Megaconstellations on existing and upcoming optical telescopes, for observations in the visible and infrared, and for various observation techniques ranging from imaging to spectroscopy, transit, transient events, *etc*. We will also discuss the case of space-based telescopes.	Dr Olivier R. Hainaut *(see 11:15 BST above)*
13:10	08:10	05:10		Large LEO satellite constellations and their impact on radio astronomy	Radio astronomy is the science of studying celestial phenomena with the observation of radio waves, radio observatories employ different types of antennas (*e.g.* fixed single dish, steerable dish, aperture arrays) tracking celestial sources in the sky. Satellite transmissions have always been a feature in the sky, and radio astronomers are used to dealing with them in low numbers or fixed positions. The recent developments on large low earth orbit constellations, with plans for several thousand of satellites using X, Ku, K and Ka bands (8 GHz to 70 GHz), will change the way radio astronomical observations will be conducted on these frequency ranges. The situation will shift from satellites being few in LEO orbit or being bound to the geo-stationary orbits, to a potential situation where a large number of satellites will be visible above the horizon and moving at great speed. This talk presents an introduction to radio astronomy and to the challenges it faces with these constellations. Touching on the regulatory aspects of the use of the radio spectrum, exiting compatibility studies between constellations and radio astronomy, and the use of Radio Quiet Zones.	Federico di Vruno *Spectrum Manager,* *SKA Observatory,UK* 
13:35	08:35	05:35		15 Minute Break		
13:50	08:50	05:50	Mitigations	An introduction to the challenges of satellite avoidance and mitigating the impact to astronomy	Since the launch of the first batch of Starlink low Earth orbit (LEO) communication satellites in May 2019, both the amateur and professional astronomical communities have expressed major concern, due to their bright apparent magnitude, caused by their very low orbits following launch and their clustering in "trains". What makes these new types of communication satellites very different from previous satellites in geostationary orbit, is the dramatically reduced orbital height and their sheer numbers, with an expected 100,000 satellites in LEO by the end of the decade. The two primary observational mitigation strategies for astronomers are avoidance and streak removal from the images, though for sensitive detectors in which the pixels are saturated, this is not a viable option. Therefore, generally, the best option is to plan observations to avoid satellite contamination. At present, this involves using publically accessible TLEs (Industry standard Two Line Elements) or ephemerides of the satellites to predict their paths across the night sky. However, this approach is limited at present due to the lack of uncertainties in the TLEs and when combined with fixed eight hourly updates, it becomes very difficult to provide accurate forecasts.	Dr Jeremy Tregloan-Reed *Assistant Professor at the Instituto de Investigación en Astronomia y Ciencias Planetarias,* *Universidad de Atacama,* *Copiapó, Atacama, Chile* 
14:40	09:40	06:40		PassPredict and TrailMask	Processing images to attempt masking of the satellite streaks. Problems with tumbling satellites. Use of ephemerides and AI to improve the masking process.	Dr Paul A. Daniels *(see Day 1, 11:00 BST above)*
14:55	09:55	06:55		Q&A		Dr Paul A. Daniels & Panel
15:20	10:20	07:20		20 Minute Break		
15:40	10:40	07:40	Future	Sharing the Sky: The IAU **C**entre for the **P**rotection of the Dark and Quiet **S**ky from Satellite Constellation Interference	The mission of the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS) is to coordinate collaborative multidisciplinary international efforts with institutions and individuals and to work across multiple geographic areas to help mitigate the negative impact of satellite constellations on ground-based optical and radio astronomy observations as well as humanity's enjoyment of the night sky. The IAU CPS is co-hosted jointly by the US NSF's NOIRLab and the SKA Observatory. The Centre will bring together regulators, astronomers, industry and the wider community and act as a bridge between all stakeholders to protect the Dark and Quiet Skies. The Centre will build on the vast work done by the community recognizing different interests of observatories according to wavelength, existing protections, and expected impact among other aspects. The vision of the Centre is to become a leading voice for astronomical matters that relate to Dark and Quiet Sky protection from satellite constellations and to act as a hub of information and resources to which any stakeholder group will be able to contribute and from which they can draw in support of their own activities.	Dr Connie Walker *Co-Director, IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS)* *Scientist and Head of the Office of Observatory Site Protection, NOIRLab, USA* 
16:10	11:10	08:10	Observations	A central repository of satellite observations and what observations are required to evaluate and help mitigate the impact to astronomy	To assess the true impact from low Earth orbit (LEO) mega constellation satellites to astronomy and help develop suitable mitigation strategies, requires the use of detailed models. The development of such models will need a statistically significant amount of data. To aid in this endeavour, NOIRLab and SKAO are forming a centralised data repository, SatHub to allow both the professional and amateur astronomical communities a place to upload their images of LEO satellites. Such a large ensemble of data will greatly aid in the development of models and forecasting software whilst providing an opportunity to assess new mitigation designs, such as the Starlink Darksat and Visorsat satellites. Here we will discuss the type of observations required to measure the satellite's brightness, BRDF, and the accuracy of the TLE along with how the amateur astronomical community can help in this international effort.	Dr Jeremy Tregloan-Reed *(see 13:50 BST above)*
16:45	11:45	08:45	Future	Satellite Constellations: international law, national policy, and industry perspectives	In 2020 and 2021, the United Nations Office for Outer Space Affairs (UNOOSA) and the International Astronomical Union (IAU), with support from NSF's NOIRLab, organized the Dark and Quiet Skies Conference I and II to mitigate the impact of artificial interferences affecting the visibility of the sky. In this context, the Satellite Constellations Working Group brought together international law experts, national regulators, satellite constellations operators and astronomers to find an equal balance in the use and access of the night sky and outer space. This presentation will summarize the findings from the working group, with a particular focus on: 1. Critical issues in international law and recommendations for continuing the discussion in international fora. 2. Recommendations to national policy-makers and regulators. 3. Best practices for satellite manufacturers and operators.	Dr Giuliana Rotola *PhD candidate,* *Sant'Anna School of Advanced Studies, Pisa, Italy* 
17:10	12:10	09:10		Q&A		Dr Paul A. Daniels & Panel
17:40	12:40	09:40		Meeting Close		Dr Paul A. Daniels