JCSA LRP Report:

The theme of the previous decade (2010-2020) has been the impact of severe funding cuts to the CSA. CSA funding decreased from 424.6M to 317.5M from 2012 through 2014. The hardest hit was Space Exploration with funding levels cut by ~50% from $165M to $88M. The 2019-2020 total planned program for Space Exploration is $107M. Prior to these funding cuts Space Astronomy in Canada was relatively healthy with PIs driven programs such as Hershel/SPIRE, Hershel/HIFI, Planck/LFI, AstroSat/UVIT, JWST/NIRISS, Astro-H and MOST all scientifically active. The CSA currently funds BRITE and NEOSSat. Mission participation is ensured for XRISM (Hitomi followup), and PI support for Euclid with main contributions coming from Canadian ground based assets (CFHT). The CSA is currently supporting a number of pre-Phase A activities. The high-energy Colibri and exoplanet polarization EPPE missions are undergoing mission concept studies. LITEBIRD, CASTOR and the microsatellite POEP mission have completed Science Maturation Studies. LITEBIRD was recently selected for Phase-0 study. Participation in SPICA/SAFARI has been maintained through the CSA Space Technology Development Program. Significant funding will be required for SPICA participation.

Highlights from the previous decade include:

1. Herschel: Canada contributed to the Herschel Space Observatory by taking part in the development of two of the three science instruments. For HIFI (Heterodyne Instrument for the Far Infrared), Canada contributed the local oscillator source unit (LSU) which is the device that provides the reference signal required for the instrument to operate properly. For SPIRE (Spectral and Photometric Imaging Receiver), Canada provided the ground-based Fourier transform spectrometer (FTS) used to test and calibrate the instrument, as well as data processing software. The For the first science results the HIFI science instrument produced a strong scientific output about detecting the presence of water in space, and resulted in 33 published papers, 25 of which were directly linked to the guaranteed time that Canada received. Canadian astronomers co-authored approximately 250 peer-reviewed science publications in just the first three years of the mission

2. Planck: The Planck mission included contributions from the Canadian Space Agency (CSA). The CSA funded two Canadian research teams that are part of the Planck science collaboration, and who helped develop both of Planck's complementary science instruments, the High Frequency Instrument (HFI) and the Low Frequency Instrument (LFI). In exchange for Canada's support, Canadian researchers were able to obtain access to the data collected by the mission on the cosmic microwave background. An early data release took place in 2011, followed by a public release of data in 2013 and a further, more complete release in 2015. 28 research papers relating to the 2015 data were published in Astronomy &

Astrophysics in October 2016. The Planck collaboration has lead to 1982 publications as of October 2019.

3. MOST: Canadian Microsatellite mission to obtain ultrahigh duty cycle and precision photometry to study stars and exoplanets. It was the first space telescope to be entirely designed and built in Canada. MOST is a small telescope dedicated entirely to asteroseismology, which is the study of star vibrations (pulsations). MOST had about 100 papers over its lifetime.

Funding cuts have seen the cancelation of mission scientist positions at the CSA and loss of astronomy research personnel. Successful programs such as SSEP (Space Expertise and Proficiency Sub-Program) and Clusters AO have not been continued. A positive highlight has been the FAST program, which began in 2010 has seen its scope increase, however, as of 2019 the total funding envelope for the program has decreased. The new Planetary and Astronomy Missions Co-Investigator 2018-19 program has started and will likely see a renewed call. If Space Exploration funding were returned to pre-2012 budgetary levels, then the CSA could potentially develop a Space Program with its own Base-A budget.

There have been a large number of studies that have been funded by the CSA and until recently mission progress has been stagnant. Official Canadian participation in WFIRST has been essentially cancelled. CASTOR has been the subject of numerous Pre-Phase A activities, but advancement to Phase-A selection has been stalled due to serious budgetary impairments. Funding CASTOR for Phase-A requires treasury board approval. Canada was a participant in the short-lived Hitomi mission and will play a role in XRISM, although personnel funding was cut to match international participation levels. Canadian Astrosat PIs are currently supported by CSA grants.

Canada will pay an important role in JWST. Canada's science return is 5% + GTO. Given its investment of $214M (estimated over a 10-yr mission) that represents less than ~2% of the total cost of JWST (~$10B). CSA has allocated $500/K per year for 5 years to fund successful Canadian GO proposals.

CSA successes and Opportunities:

- FAST program
- CSEW activities
- Pre-Phase A mission studies (Concept, SMS, MCS)
- JWST GO Program
- Planetary and Astronomy Missions Co-Investigator Program
- First NEOSSat AO in September, 2019.

Both BRITE and NEOSSat operations are currently funded by the CSA, but future potential for continued operations funding is limited. The JCSA was pursuing a grant program to be administered jointly by NSERC and the CSA to fund astronomical research performed using Canadian space assets. There has been limited development. The JCSA should renew effects to have joint NSERC and CSA programs. Beyond the CSA there are few alternatives for space exploration research projects

The CSA is currently studying four missions that have the potential to be truly Canadian Led programs: POEP, CASTOR, EPPE and Colibri. ROM cost estimates range from $20M to more than $500M for the listed missions. Optimistically, if all four missions where selected for Phase-A immediately after conclusion of pre-phase A activities, potential launch dates and start of Phase-D activities could begin in 2025 and 2026 for POEP and CASTOR and likely early to mid 2030s for EPPE and Colibri. Ideally, Canada requires a balanced program of small to large programs, but obviously funding is the major hurdle.

Overall recommendations:

- Return funding to CSA Space Exploration to pre-2012 budgetary levels.
- A Canadian Space Program with stable and predictable funding.
- Increased staff and reintroduction of CSA staff scientists with guaranteed research time.
- Joint NSERC-CSA grant program to fund astronomical research performed using Canadian space assets
- Maintain stable funding for the FAST program
- Mission Down-select process to enable missions to proceed to Phase-A

JCSA Notes For Missions Not Covered by LPRIC Space Astronomy WP

MOST

The **Microvariability and Oscillations of Stars** telescope (MOST) was lost in March, 2019 due to an apparent failure of a power subsystem. MOST had operated commercially since October 2014 after recommendations from the JCSA to prioritize funding to other space assets/opportunities.

NEOSSat

The CSA NEOSSat mission is jointly operated by the CSA and DRDC and is currently being used to obtain observations of solar system objects and transiting exoplanets. These observations are used for both scientific purposes and to characterize the photometric capabilities to enable open observing time to the Canadian community. The first NEOSSat AO was issued in September. 2019.

Astrosat-UVIT

Astrosat has completed more than 3 years in orbit, of its 5-year design lifetime. With 5 instruments, containing 14 independent instrument systems, it has had few failures: currently one of the 3 LAXPC units is not working, and the UVIT NUV detector. Canadian PIs continue to use our 5\% share of observing time.

CADC

The CADC was initiated in 1986 to serve HST data and promote Canadian HST participation. The CADC has become an essential facility to the Canadian community hosting data from Canadian facilities such as CFHT and MOST. With the imminent launch of the James Webb Space Telescope the CSA and CADC signed a 5 year memorandum of understanding (MOU) at $200 K/year to mirror JWST data. In spite of significant financial pressures on CSA's Space Exploration budget, additional supplementary funding of 100K per year has been approved up to 2019-20.

BRITE

BRITE (BRIght Target Explorer) Constellation international collaboration between Canada, Austria and Poland. Together a network of five nanosatellites are used to investigate stellar structure and evolution of the brightest stars in the sky and their interaction with the local environment. The BRITE instrument consists of a 3-cm telescope with a wide-field of view to continuously monitor the brightest stars observed in the night sky. A campaign typically lasts 160-180 days which provides a unique dataset that cannot be duplicated with any existing infrastructure. Canadian Science and operations have been supported by grants from the CSA, however, grants have been issued on short-time scales of 1 year which has meant a lack of financial stability. Due to a gap in funding, operations where temporarily suspended resulting in a loss of science acquisition. The BRITE team was asked by the CSA to investigate alternate means of science funding, such as NSERC. However, within the Canadian funding system there is no program that can sufficiently and reliably provide operational funding for the satellite. This message was delivered to the CSA.

The BRITE mission is currently operational and reaching maturity as a science mission. The lack of stable and predictable funding has eroded confidence and relations with industry partners and has inhibited the science team from the ability to make multi-year term commitments within the international collaboration. Canada is the only partner that has not established a financial commitment to BRITE.

JWST

The James Webb Space Telescope (JWST) is a 6.5 meter infrared space telescope that will serve most, if not all, of the Canadian astronomical community. With an investment of $170M the CSA has contributed the Fine Guidance Sensor (FGS), as well as one of the telescopes four science instruments: the Near-InfraRed Imager and Slitless Spectrograph (NIRISS). JWST represents the largest Canadian investment in Space Astronomy. JWST will contribute to studies

of the Solar System, extrasolar planets, stars, interstellar medium, galactic, extragalactic, early universe studies and more. Canadian science will supported by grants from the CSA to successful ERS, GTO and GO proposals. The JCSA is working in collaboration with the CSA to form a sub-committee to develop policy and rules for the allocation of JWST-GO funds. This process must be completed on a short timescale well in advance of the GO Cycle 1 deadline.

XRISM

SWG funding has been provided at 25K/yr per member. Having a multi-year grant would be appreciated to avoid having to apply for a grant amendment on an annual basis.

There was a serious lack of transparency for CSA funded team members over transition from Hitomi to XRISM. XRISM is an important example that highlights the lack of process for allocation of mission funding. This was an oversight from both the JCSA and CSA that had assumed HITOMI team members were in communication over team membership.

EPPE

EPPE is a polarization concept study for exoplanets and brown dwarfs. EPPE had its first kickoff meeting on Nov 8, 2018 following the FSAC18. workshop in Montreal. The project has noted issues regard efficiency of funds for concept development. The allowed overhead is 57% which can severely limit scientific study during concept timescale. Science must drive astronomy satellite development.

Colibr`ı

The Colibr`ı began their science concept study in September, 2018. The science case is built upon the concept of a high-energy resolution x-ray telescope (one part per thousand) over the approximate energy range of 0.2 to 10 keV combined with high-throughput (10-200 kHz) and high-time resolution (sub microsecond). It would achieve this using non-focussing optics with TES x-ray detectors. The team is investigating the potential scientific investigations, detector development and the payload design in partnership with universities across Canada, Honeywell and Maxar. The Colibri concept represents a large fraction (is not all) of the high energy astronomy community in Canada. Colibri would be a Canadian Flagship mission.

POEP

The CSA has funded a Science Maturation Study for Photometric Observations of Extrasolar Planets (POEP) to use the BRITE and MOST mission concepts to raise the Science Readiness Level for a UV/IR mission. The Science is the discovery and characterization of extrasolar planets through photometry with a UV and IR channel. The near-IR capabilities will enable the discovery of transiting Earth-sized planets in the HZ of brown-dwarfs and the UV

capabilities will characterization the atmosphere of transiting planets around bright host stars and potentially act a biomarker detector. The CSA is providing guidance to help drive necessary technology development in anticipation of targeting 2022 Federal Innovation Funds (CFI) to build satellite with a potential launch date of 2025.

CASTOR

The CASTOR mission is a proposal to construct a *Canadian led* 1-m class UV, widefield space telescope with a primary science goal of furthering our understanding of Dark Energy in the Universe. CASTOR contributes to dark energy exploration by providing the UV/blue spectral energy distribution coverage needed by both WFIRST and Euclid for accurate photometric redshift measurements. The CASTOR mission continues to represent the bar that Space Astronomy in Canada should strive to achieve. The CASTOR mission was originally supported by various technical studies to reduce risk. The MTRP recommended that CASTOR proceed to Phase 0. The CASTOR team is currently undergoing a CSA funded Science Maturation Study to explore risk, full cost estimates and the potential of additional international collaboration. There is significant interest in international participation in the CASTOR mission concept, however, without serious commitment to CASTOR to be a selected mission all international partnerships are at risk.

LITEBIRD/SPICA

The CSA has invested in signature Canadian technology that has become the enabling baseline for international partnership missions such as LiteBIRD and/or SPICA. To bear fruit from these investments, a path must be created to compete within Canada for funded mission status, in partnership with international agencies. This competition would assess mission relevance, science return, risk, timeliness, Canadian content, and industrial contributions. The maturation of technology within Canada, and its role for missions, makes it essential that this is addressed within a year.

WFIRST

The failure of WFIRST must be understood. Despite repeated attempts from the CSA to obtain Federal funding, messages to the SAB and direct participation of the CASCA President, a financial contribution to the WFIRST mission from the Federal government could not be secured. The JCSA is concerned that the vacuum that exists between the academic community and those that make funding decisions. The current vague process does not provide sufficient feedback to adequately understand how to improve messaging or requirements. The potential loss of credibility to the CSA is difficult to ignore and its impact on the ability of the CSA and Canada to participate in large international missions.

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There is still confusion regarding the descope of the IFC and the positions of NASA and the CSA. The CSA informed the JCSA that the IFC was descoped because the CSA could not secure federal funding in a timely fashion to meet schedule for delivery to NASA. Clarification of events leading to the failure of WFIRST participation will be hashed out at the next meeting

ULTRASAT

The ULTRASAT mission, with a targeted launch in 2021, aims to provide a wide-field, UV time-domain survey to increase our understanding of the hot transient universe. The primary science goals are to detect UV Emission from Gravitational Wave Sources and study the Deaths of Massive Stars. In particular, the recent detection of gravitational waves represents a new and exciting window to observe the Universe. The ULTRASAT mission highlights time domain astrophysics, and has a focus on compact objects and high energy phenomena, both areas where the Canadian scientific community has an exceptional reputation.
The JCSA had recommended Canadian participation in the ULTRASAT mission. Following a presentation to SE Steering Committee, the decision was to decline the invitation/opportunity for ULTRASAT with the lack of budget and short timing as contributing factors. The CSA however, did not rule out a Canadian scientific contribution at a later date. The JCSA will track future developments of the ULTRASAT project and potential Canadian involvement

ACEND

There is Canadian interest for participation in the ACEND (Alpha CENtauri Direct imager) project. ACEND is a 40-cm coronagraphic space telescope concept that will directly image the planetary systems of Alpha Centauri (A and B) in 3 visible bands, with the capability of recognizing Earth-like planets (exo-Earths) and assessing their potential for habitability.

CSA Grants and Contracts

The CSA has issued a number of RFPs including targeted Studies (SMS for CASTOR, Contribution Study for LiteBIRD), open Concept studies, open SMS calls, and FAST2017 for targeted HQP training. A STDP RFP for technology development was announced in 2019.

The CSA is continuously soliciting feedback for specific technologies to support missions through STDP that are identified in the CSEW report. Contracts are usually awarded to industry partners and could provide funding of $0.5M to 1M CDN with a few million dollars available per year to support a variety of projects

The FAST program has a funding envelope of $6M. FAST programs are targeted towards the training of HQP. The last FAST AO received 70 responses and the next opportunity is coming soon.

Contracts were issued for targeted studies for the CASTOR mission concept and LiteBIRD mission. The CSA, through PSPC (Public Services and Procurement Canada), issued 5 SMS contracts, with 2 in Space Astronomy and 3 in Planetary. One space astronomy contract was to Bishop's University to study transiting extrasolar planets with a BRITE or MOST-like mission

and the other contract to McGill for a SMS on LiteBIRD for science requirements and flow them down to the McGill detector readout electronics. The program saw an oversubscription rate of approximately 2. It was noted, that proposal teams can request aggregated feedback through Public Works. The JCSA believes that proposal feedback should be provided to proposal teams by default.

The Concept Study RFP received 10 proposals with 4 in Space Astronomy and 6 in Planetary. CSA funded 2 proposals in Space Astronomy The JCSA has expressed concern that proposals are not peer reviewed. The membership of CSA review panels are not known. Regulations currently require basic security assessment of potential panel members, which could produce a significant amount of overhead for the CSA to review proposals on a timely manner. The JCSA believes that Peer Review is an important component of the proposal and selection process and the CSA should investigate how to incorporate Peer Review.