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Special Section Guest Editorial: SALTUS Probe-Class Mission Concept

Jonathan Arenberg[a,*] **and Jian-Rong Gao**[b]
[a]Northrop Grumman Corporation, Falls Church, Virginia, United States
[b]Netherlands Institute for Space Research, Groningen, The Netherlands

In response to the recently concluded Astrophysics Decadal Survey which called for new mission concept, the Astrophysics Probes, a $1 billion cost-capped principal investigator (PI) led the mission. NASA issued an announcement of opportunity in July of 2023. The announcement called for two kinds of missions: a far-infrared and an X-ray mission. This mission class is designed to fill the gap between flagship and smaller-scale missions in NASA's Explorers Program. As such, at least 70% of the observation time is allocated to guest observers, with 30% reserved for a core science program as defined by the PI and the science team. The selection process is organized in two steps: initially one proposal per each type (far-infrared and X-rays) is selected for a 12 months-long Phase A feasibility study starting at the end of 2024; after this study, one proposal is approved for a launch currently expected in July 2032. The selections for the initial feasibility or Phase A study have been made and our mission, "Single Aperture Large Telescope for Universe Studies" (SALTUS), was unfortunately not selected.

The SALTUS mission takes its name from the Latin for "a jump" and having the English definition, of a sudden transition or a breach of continuity. We gave the mission this name for the very large primary mirror at the center of this mission concept. While proposing a large mirror for a space mission is hardly new, SALTUS's primary mirror is 14 m in diameter and is inflatable. This JATIS special section is almost evenly split with five papers discussing the science that is enabled with such a large aperture and four dedicated to the implementation of this paradigm shifting concept.

Chin et al. (DOI 10.1117/1.JATIS.10.4.042310) provide an overview of SALTUS capabilities and the science observations, both planned by the science team and the guest observer capabilities that are achievable with such an observatory. SALTUS's spectral range, $34 - 660\ \mu$m, complements Webb and ALMA well and will have 16× the collecting area and 4× the angular resolution of Herschel. With a large aperture enabling high spatial resolution and sensitive instruments, SALTUS will offer >80% of its available observing time to Guest Observer programs, providing the science community with powerful capabilities to study the local and distant universe with observations of 1000s of diverse targets such as distant and nearby galaxies, star-forming regions, protoplanetary disks, and solar system objects.

Anderson and co-authors (DOI 10.1117/1.JATIS.10.4.042302) present the exciting solar system science that SALTUS would enable. The high sensitivity and high spectral resolving power of the SALTUS heterodyne receivers enable both submillimeter and far-infrared observations of trace compounds comprising water and its isotopologues, hydrogen deuteride (HD), and a plethora of molecular species containing carbon, hydrogen, nitrogen, oxygen, phosphorus, or sulfur (CHNOPS), all of which are obscured by the Earth's atmosphere. The high sensitivity and broadband spectral coverage of the SALTUS far-infrared grating spectrometer enables far-infrared observations of the lattice vibrational spectral signatures of ices and mineral grains contained within a wide variety of solar system targets, including comets, planetary atmospheres, near Enceladus' plumes, and on the surfaces of icy moons, Jupiter trojans, centaurs, and Kuiper

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*Address correspondence to Jonathan Arenberg, jon.arenberg@ngc.com

Belt objects. The extensive amount of solar system science achievable with SALTUS for both the Guaranteed Time Observation and the Guest Observer APEX mission observing programs is also reviewed.

Schwartz et al. (DOI 10.1117/1.JATIS.10.4.042307) report on the plans for the investigation of star and planet formation that are possible with the SALTUS observatory. Spectroscopic observations in the far-infrared offer many unique windows into the processes of star and planet formation. These include observations of low-energy water transitions, the H_2H_2 mass tracer HD, many CHONS constraining molecules such as NH_3NH_3 and $H_2SH_2S_2$, and emission lines from the phonon modes of molecular ices. Observing these species will allow us to build a statistical sample of protoplanetary disk masses, characterize the water snowline, identify Kuiper Belt-like debris rings around other stars, and trace the evolution of CHONS from prestellar cores, through to protoplanetary disks and debris disks. Several key star and planet formation science goals achievable with SALTUS are also detailed.

Levy and co-authors (DOI 10.1117/1.JATIS.10.4.042304) discuss Milky Way (MW) and nearby galaxy science possible with SALTUS. These science goals focus on understanding the role of star formation in feedback in the local universe. In addition to this science case, SALTUS would open a new window to galactic and extragalactic communities in the 2030s, enabling fundamentally new questions to be answered, and would be a far-IR analog to the near- and mid-IR capabilities of the James Webb Space Telescope. MW and nearby galaxy science case and plans for notional observing programs in both guaranteed and guest (open) times are also discussed.

Spilker et al. (DOI 10.1117/1.JATIS.10.4.042305) present the science case for high-redshift extragalactic observations possible with SALTUS. Enabled by its 14-m primary reflector, SALTUS offers enormous gains in spatial resolution and spectral sensitivity over previous far-IR missions. SALTUS would be a versatile observatory capable of responding to the scientific needs of the extragalactic community in the 2030s and a natural follow-on to the near- and mid-IR capabilities of JWST. The key early-universe science goals for SALTUS focus on understanding the role of galactic feedback processes in regulating galaxy growth across cosmic time and charting the rise of metals and dust from the early universe to the present. We summarize these science cases and the performance metrics most relevant for high-redshift observations.

Harding and coauthors (DOI 10.1117/1.JATIS.10.4.042303) present a detailed look at SALTUS mission architecture. The observatory flight system is based on Northrop Grumman's LEOStar-3 spacecraft platform. The payload consists of the inflation control system, sunshield module (SM), cold corrector module (CCM), warm instrument electronics module, and primary reflector module (PRM). The 14-m M1 is an off-axis inflatable membrane radiatively cooled by a two-layer sunshield. The CCM corrects for residual aberration from M1 and delivers a focused beam to two instruments—the High-Resolution Receiver (HiRX) and SAFARI-Lite. The CCM and PRM reside atop a truss-based composite deck that also provides a platform for the attitude control system. The SALTUS 5-year mission lifetime is driven by a two-consumable architecture: the propellant system and the inflation control system. The core interface module (CIM), a multi-faceted composite truss structure, provides a load path with high stiffness, mechanical attachment, and thermal separation between the Payload and spacecraft. The SM attaches outside the CIM with its aft end integrating directly to the bus. The spacecraft maintains an attitude off M1's boresight with respect to the Sun line to facilitate the thermal environment. SALTUS will reside in a Sun–Earth halo L2orbit with a maximum Earth slant range of 1.8 million km, reducing orbit transfer delta-v. The instantaneous field of regard provides two continuous 20 deg viewing zones around the ecliptic poles, resulting in full sky coverage in 6 months.

Arenberg et al. (DOI 10.1117/1.JATIS.10.4.042306) concentrate their contribution on the primary mirror for SALTUS, called M1. The focus on this limited subject matter is due to its importance to SALTUS and potentially other space observatories. An historical overview of inflatable systems is presented, and the authors argue that M1 is the logical next step in the evolution of such systems. The process of design and manufacture of a large precision inflatable reflector is addressed. The performance of M1 in its environment in terms of the operating temperature, interaction with the solar wind, and shape change due to non-penetrating particles is analyzed and presented. A key question of the longevity of the inflatant is analyzed in detail. This analysis shows that M1 will meet mission lifetime requirements with ample margin.

Kim and co-authors (DOI 10.1117/1.JATIS.10.4.042309) discuss the entire optical system design. The unique SALTUS optical design, utilizing a large inflatable off-axis primary mirror, active correction delivers excellent angular resolution, and imaging performance at far-IR wavelengths over a wide ±0.02 deg ×0.02 deg field of view. SALTUS' design, with its highly compact form factor, allows it to be readily stowed in available launch fairings and subsequently deployed in orbit.

Silva et al. (DOI 10.1117/1.JATIS.10.4.042308) discuss the High-Resolution (heterodyne) Receiver (HiRX). HiRX consists of four bands of cryogenic heterodyne receivers with a high sensitivity and high spectral resolution, being able to observe the gaseous components of objects across the far-IR. HiRX is going to detect water, HD, and other relevant astrophysical lines while resolving them in velocity. HiRX covers the following frequency ranges: Band 1 from 455 to 575 GHz, Band 2 from 1.1 to 2.1 THz, Band 3 from 2.475 to 2.875 THz, and Band 4 for both 4.744 and 5.35 THz. Bands 1 to 3 contain single, high-performance mixers. Band 4 consists of an array of seven hexagonally packed pixels, where the central pixel operates as a heterodyne mixer. Band 1 utilizes superconducting-insulator-superconducting mixers (SIS), whereas Bands 2 to 4 use superconducting hot electron bolometers (HEB) mixers. The local oscillator (LO) system uses frequency-multiplier chains for Bands 1 and 2, and quantum cascade lasers for Bands 3 and 4. Autocorrelator spectrometers are used to process the intermediate frequency (IF) signals from each science band, providing instantaneous frequency coverage of 4 to 8 GHz for Band 1 and 0.5 to 4 GHz for Bands 2 to 4. SALTUS will also fly a chirp transform spectrometer system for high spectral resolution observations in Band 1.

The authors and editors of this JATIS special section are eager to share our work on the SALTUS concept despite our disappointment at not being selected. We contribute this work in the belief that a future mission concept based on this technology with future evolution will produce the eponymous break with tradition that will power a new era in far-IR science.