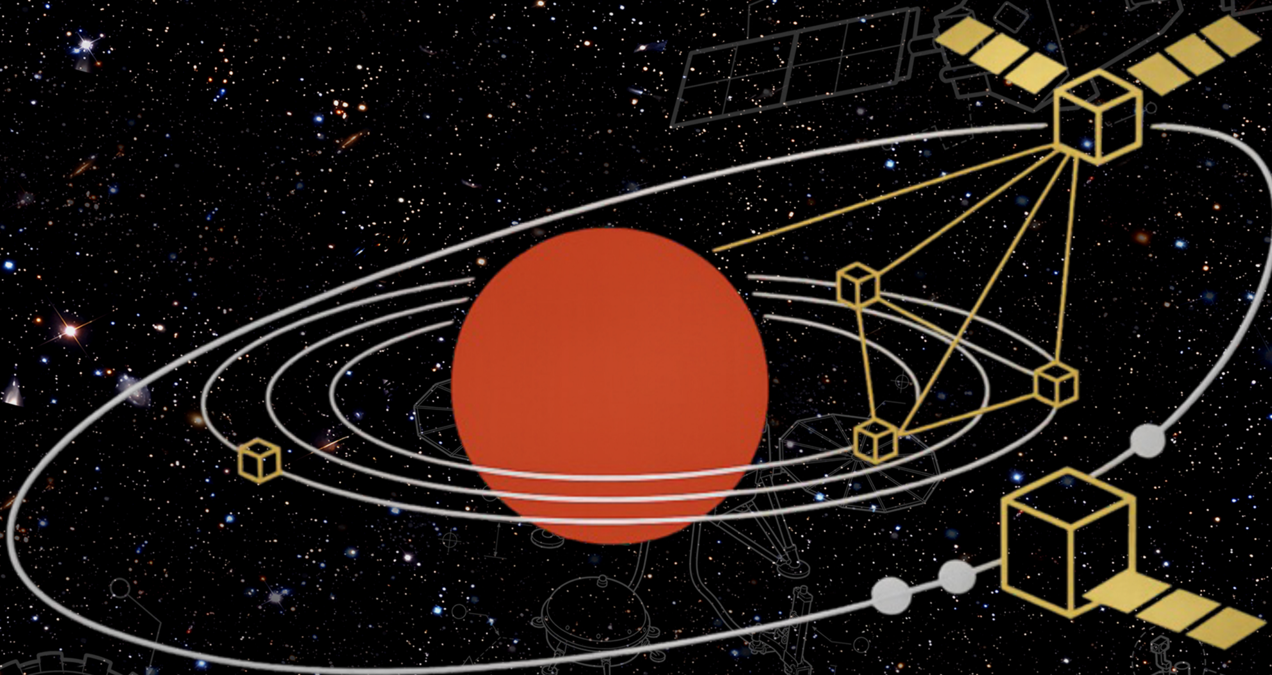
A New Era of Space Science: Actionable and Affordable Mission Plans

Final Report: August 2026



Keck
Institute for Space Studies

A New Era of Space Science:
Actionable and Affordable Mission Plans

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Study Leads:

Mark McElroy, Benchmark Space Systems
markwmcelroy@gmail.com

Sona Hosseini, Jet Propulsion Laboratory, California Institute of Technology
sona.hosseini@jpl.nasa.gov

Andy Klesh, Brinson Exploration Hub & Jet Propulsion Laboratory, California Institute of Technology
klesh@caltech.edu

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Executive Director: Harriet Brettle

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Workshop Participants

Don Banfield, NASA Ames	Charles Beyrouthy, Forma Prime
Ben Bussey, Intuitive Machines	Julie Castillo-Rogez, ASU
Jacob Clarke, SDL	Elizabeth Congdon, John Hopkins, APL
James Cutler, University of Michigan	Giusy Falcone, University of Michigan
Gwen Hanley, UC Berkeley	Sona Hosseini, Jet Propulsion Laboratory, Caltech
Andrew Klesh, Brinson Exploration Hub, Jet Propulsion Laboratory, Caltech	James Mason, John Hopkins, APL
Mark McElroy, Benchmark Space Systems	Carolyn Mercer, NASA HQ
Trent Newswander, SDL	Katherine Park, Brinson Exploration Hub, Caltech
Mona Postma, Jet Propulsion Laboratory, Caltech	Jason Rhodes, Jet Propulsion Laboratory, Caltech
Max Roberts, Muon Space	Griff Russell, Gryphon Effect LLC
Julianna Scheiman, SpaceX	Caitlin Smith, SpaceX
Leon Thomm, ETH Zurich	Jessica Todd, Caltech
Frank Webb, Jet Propulsion Laboratory, Caltech	Jason Willis, Jet Propulsion Laboratory, Caltech

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Executive Summary

The Keck Institute for Space Studies (KISS), in partnership with the Brinson Exploration Hub at Caltech, convened 26 experts from academia, industry, and NASA in July 2026 for the symposium, **“A New Era of Space Science: Actionable and Affordable Mission Plans.”**

Over 2.5 days, participants examined **paradigm-shifting approaches to space science missions** and identified **Affordability Improvement Measures (AIMs)** with the potential to significantly reduce mission costs while preserving scientific impact.

The Symposium was designed to move from ideas to action. Participants identified concrete opportunities to apply these approaches within their organizations, incorporate them into mission concepts, and influence how future space science missions are designed, developed, and executed.

Breaking Barriers for a New Era of Space Science

The Symposium identified six Paradigm-Shifting Ideas as having the greatest potential to make space science missions more affordable. The ideas were prioritized in the Symposium based on three factors: implementation effort, departure from current practices, and potential impact on mission affordability. This approach allowed for both reembracing older ideas and developing new ones.

1. **Expand How Space Science Is Funded**: Connect science with non-traditional funding and sponsor priorities, supported by more entrepreneurial approaches, private capital, recurring opportunities, and shared scientific, commercial, technical, or operational value.

2. **Enable Missions to Capitalize on Shared Flight Opportunities**: Improve visibility, readiness, coordination, and payload compatibility so missions can take advantage of rideshare, hosted payload, excess capacity, and other shared opportunities.

3. **Reduce Mission Cost by Reducing Time to Execution**: Treat time as a primary affordability lever by aligning teams, partnerships, funding profiles, contracts, procurement, and key decisions around rapid execution. Be ready for serendipitous mission opportunities and prioritize fast decision making - consider forward-leaning purchases and builds.

4. **Co-Create Missions by Iterating Between Science and Capabilities**: Formulate missions around both science needs and available capabilities, creating

pathways to focused, high-value science. Consider inverting the proposal process to take advantage of mission capabilities to drive science possibilities.

5. **Transform and Accelerate Proposal and Selection**: Use shorter, focused, phased proposals and fit-for-purpose review processes to reduce pre-selection investment, accelerate decisions, preserve strong concepts, and support multidisciplinary and time-sensitive opportunities.

6. **Integrate Software and Artificial Intelligence Expertise Across Mission Teams**: Embed software, artificial intelligence/machine learning, and domain expertise across mission teams to enable onboard processing and autonomy, reduce downlink constraints, streamline execution, and improve efficiency.

Affordability Improvement Measures (AIMs)

The **Affordability Improvement Measures (AIMs)** are high-priority practices identified by Symposium participants to reduce the cost of space science missions while maintaining scientific value. Drawing on both existing research and new concepts developed during the Symposium, the AIMs provide the foundation for Paradigm-Shifting Ideas.

- **Programmatic Incentives & Business Models**
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  - AIM-2: Leverage commercial mission service/tech providers and financial vehicles
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- AIM-12: Define mission success to recognize partial achievement of science and technical objectives

- **Verification & Test Approaches**
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  - AIM-16: Use bulk procurement to reduce cost, long-lead times, and availability constraints
- **Reviews & Documentation**
  - AIM-17: Structure reviews to add project value while maintaining execution pace
  - AIM-18: Streamline decision-making to accelerate mission execution

1. Introduction

This study convened science and engineering experts from government, academia, and the commercial space sector to address a central challenge: **making ambitious Moon and Mars science missions dramatically more affordable and achievable in the near term.** Building on more than a decade of work on low-cost missions, the study examined how advances in technology, evolving industry practices, and current institutional realities could enable new approaches to mission development and execution.

The Symposium used pre-defined exemplar Moon and Mars missions with a **$30 million cost cap** to ground the discussion in credible mission scenarios without turning the effort into a mission design exercise. Participants drew upon prior research and their own experience to identify cost-reduction opportunities, examine differing perspectives on risk posture, roles, and value delivery, and determine where changes to mission design, management, and institutional processes could have the greatest impact.

The study produced two complementary sets of recommendations. **Affordability Improvement Measures (AIMs)** identify priority practices for reducing mission costs. **Paradigm-Shifting Ideas**, developed by synthesizing AIMs and other concepts toward the end of the Symposium, represent broader approaches considered potentially disruptive and high-impact. Together, these recommendations provide a basis for advancing more affordable space science missions toward near-term execution.

The full Symposium agenda is included in Annex 1.

This Symposium was organized in partnership with the Brinson Exploration Hub.

2. Breaking Barriers to a New Era of Space Science

The **Paradigm-Shifting Ideas** emerged from a rapid mission-pitch exercise designed to challenge conventional approaches to Moon and Mars science. Twelve teams had one hour to develop a science mission for less than **$30 million** and deliver a one-slide, one-minute pitch. The exercise surfaced creative approaches that differed from those commonly found in the literature, and notably, **none required the development of new technology**. These concepts were subsequently consolidated and refined into the Paradigm-Shifting Ideas presented below, informed by the broader Symposium discussions and findings in this report.

[1] Expand How Space Science Is Funded

Non-traditional funding, including philanthropic and other private capital, could expand opportunities for affordable space science, but these sources remain difficult to access. Unlike established NASA programs, private funding can be less transparent, more opportunistic, and dependent on relationships. Addressing this gap will require stronger connections between science needs and potential sponsors, as well as a more entrepreneurial mindset among scientists and their institutions that translates compelling science concepts into credible funding and business cases.

Attracting new sponsors may also require aligning scientific objectives with commercial, technical, or operational value. This does not mean compromising the science but rather identifying shared objectives that advance both scientific and sponsor priorities. This alignment may require adapting risk tolerance, team and contracting structures, measures of success, and portfolio strategies to reflect the priorities and operating models of different sponsors.

Recurring, lower-cost programs with multiple flight opportunities could improve affordability by building continuity and capturing efficiencies across missions. NASA's Commercial Lunar Payload Services (CLPS) initiative demonstrates elements of this model by providing recurring opportunities to fly science and technology payloads on commercial lunar deliveries. More broadly, programs could increase flexibility by maintaining a catalog of instruments available for rapid selection and development as funding or flight opportunities emerge.

[2] Enable Missions to Capitalize on Shared Flight Opportunities

Current mission formulation and planning processes are not structured to take full advantage of rideshare, hosted payload, and other shared-resource opportunities. Greater transparency into available opportunities, provider capabilities, interfaces, requirements, and constraints allows teams to **design for flexibility from the outset and transition more readily between providers and flight opportunities**. Common interfaces and requirements, where practical, further reduce integration time and cost. These opportunities still require early investment in spacecraft compatibility and instruments capable of accommodating a broader range of flight environments and constraints without compromising primary mission objectives.

Greater coordination connects available capacity with science needs. An organization or coordinating function with visibility across missions and flight opportunities identifies potential matches, aligns incentives, and helps operators make productive use of excess capacity. **Together, transparency, flexibility, and coordination shift shared flight opportunities from serendipitous events toward a deliberate and scalable pathway for affordable science.**

[3] Reduce Mission Cost by Reducing Time to Execution

Time to execution is a fundamental driver of mission affordability, shaping project scope, team and partnership models, funding profiles, contracting and procurement strategies, and the ability to capitalize on emerging flight opportunities. Longer timelines increase labor costs, allow requirements and scope to grow, and can leave missions unable to respond to time-sensitive or serendipitous opportunities.

Proven team and partner relationships can be a powerful enabler of rapid execution. Established interfaces, roles, and ways of working reduce coordination overhead, while effective tools and practices can streamline workflows, meetings, and communication, allowing teams to focus resources on mission delivery.

Mission structures should reinforce the intended pace. Early access to funding can enable procurement of long-lead, bulk-buy, or multi-project items, while contracts, procurement approaches, and milestone-based payments should incentivize timely progress. Major architectural decisions, including launch provider, communications architecture, and spacecraft bus, should be resolved early to minimize redesign while preserving flexibility where it adds value. Sponsors should also be prepared to stop projects that fail to meet critical objectives rather than continue investing based on sunk costs.

[4] Co-Create Missions by Iterating Between Science and Capabilities

Affordable missions should emerge from an iterative exchange between scientific ambition and technical, programmatic, and flight opportunities. Traditional mission formulation often begins with science objectives and flows through a Science Traceability Matrix (STM) from science requirements to mission and system design. The new era of space science calls for formulation that works in both directions: science objectives drive technical solutions, while available and emerging technologies, instruments, platforms, funding, and flight opportunities open new pathways for scientific discovery. This iterative approach can align scientific ambition and scope with cost, schedule, and risk to deliver focused, high-value science.

Co-creation should bring scientists, technologists, engineers, program managers, funding partners, and other key stakeholders together from the outset to converge on an executable mission concept. Proven capabilities and targeted innovation both have a role: existing instruments, technologies, components, and platforms can accelerate execution and reduce cost, while targeted development can enable new science and capabilities. Illustrative mission costs include roughly $85 million for Mars Ingenuity, $18.5 million for MarCO, $13 million for LunaH-Map, and PRISM which is targeting single-digit millions to deliver new instruments to the lunar surface. These examples demonstrate how focused development can advance science and technology at lower cost. Such missions can contribute to a broader portfolio spanning frontier science, technology development, scaling of emerging capabilities, and new concepts that can be tested and built upon.

[5] Transform and Accelerate Proposal and Selection

The cost of an affordable mission begins before selection. For lower-cost missions, many proposals and very low selection rates drive substantial community-wide investment before a mission is selected. A shorter, focused, and phased proposal process addresses this by requiring only the information needed for initial evaluation and developing greater detail as concepts advance. This concentrates effort where it adds value while maintaining rigorous evaluation tailored to each opportunity's objectives.

The selection process should also preserve and build on strong concepts. Carrying strong, unfunded concepts into future opportunities retains prior investment, accelerates selection, and increases readiness for time-sensitive opportunities. For technology demonstrations and rapid flight opportunities, a unified review process spanning Planetary Science, Astrophysics, and Heliophysics reduces review time and enables multidisciplinary missions across traditional disciplinary boundaries. Peer review and decision gates tailored to mission objectives, cost, schedule, and risk align the selection model with the scale and pace of affordable missions.

[6] Integrate Software and Artificial Intelligence Expertise Across Mission Teams

Software, artificial intelligence (AI), and machine learning (ML) expertise should be integrated directly into mission teams. Engineers who combine emerging AI/ML capabilities with domain expertise across science, engineering, implementation, and operations bring a powerful skill set that connects mission objectives with new approaches to data processing, autonomy, and execution.

This integration is particularly valuable when data downlink is constrained. Onboard processing, including AI/ML on resource-constrained computing platforms, can prioritize, reduce, or interpret data before transmission, increasing scientific return within available communications capacity. Embedding this expertise throughout mission formulation and execution also streamlines development and operations, improves efficiency, and reduces mission risk.

3. Affordability Improvement Measures (AIMs)

The Affordability Improvement Measures (AIMs) are specific actions that reduce mission cost and improve execution efficiency, essential to enabling a new era of space science. They translate lessons learned, recommendations, and practices from prior missions and studies into actionable changes across mission development, management, engineering, acquisition, and execution.

The AIMs were developed through extensive work before and throughout the Symposium. A review of 28 references (see Annex 2), including prior studies, NASA reports, documented lessons learned, and recommendations, identified 938 individual measures and ideas related to mission affordability and efficiency. These were synthesized and consolidated into 67 AIMs that provided the starting point for Symposium deliberations.

Participants then tested these AIMs against their own experience, refined and expanded them, identified gaps, and prioritized the measures with the greatest relevance to current mission environments. This process produced the final 18 AIMs presented below. Together, they provide a focused set of actions for improving how affordable space science missions are formulated, developed, and executed, and underpin many of the Paradigm-Shifting Ideas presented in Section 2. The 67 AIMs synthesized from the literature review are provided in Annex 2.

[1] Programmatic Incentives & Business Models

AIM-1	Strengthen coordination across agencies, mission teams, industry, users, and funders
Barriers to Adoption	● Sensitive information (ITAR/EAR, IP, proprietary) ● Unclear definitions of success ● Conflicting incentives between organizations ● Having the conversation at all meetings without a key stakeholder (e.g., science) ● Few unified hubs of information ● Over-reliance on aerospace heritage supply chain (consider alts. like automotive)
Potential Impact	● Greasing the skids into more opportunities ● Better utilization of resources (e.g., same instrument with multiple applications) ● Enable quick pivots and more flexibility ● Coupling of industries leading to economic/job growth and therefore sustained congressional support (virtuous cycle), clearer role definitions ● Shorter time to science, better access/utilization to/of capital, non-diluted funding attracts private funding, reduces risk (upon repeated uses), efficiency and greater operational execution
Implemen-tation	● Multiple agencies unknowingly need similar things and should coordinate and/or potential proposers can bring this to their attention ● Setting up a platform, group, or node that can serve the whole community & bring together all stakeholders (e.g., PMs) to facilitate these conversations.

AIM-2	Leverage commercial mission service/tech providers and financial vehicles
Barriers to Adoption	● ICDs not easily accessible & a lack of standardization ● Awareness of all available financial vehicles ● Institutional T&C (e.g., overhead rates) ● Company going out of business introduces increased procurement risk, makes timely access to the tech uncertain. Logistics/legal/organizational challenges. ● Loss of control ● Lack of commercial incentives for (deep space) planetary missions
Potential Impact	● Shorter time to science ● Better access/utilization to/of capital for lower-cost innovative solutions ● Non-dilutive funding can help catalyze and attract follow-on private investment. ● Reduces technical risk through repeated use and demonstrated operational heritage. ● Efficiency and greater operational execution
Implemen-tation	● Create a "DigiKey for spacecraft": a centralized platform providing transparency into commercial products, capabilities, and supply chains. Vendor participation is required to increase the platform's value as both a sourcing tool and marketing channel. ● Maintain IP continuity plan (in case of company closure) ● More transparency around how to engage with venture capital ● Develop select AOs that require proposers to leverage commercial vendors from a predefined set of qualified providers

[2] Teams and Teaming

AIM-3	Use small, flat, co-located multidisciplinary teams and consistent independent assessors across the mission lifecycle
Barriers to Adoption	• Legacy processes/culture • Institutional reflexes/cultural norms • Prescriptive proposal calls/risk class
Potential Impact	• Lower labor costs (smaller teams) • More agile teams with broad system-level understanding • Less restrictive requirements • Efficient science & more innovative missions
Implemen-tation	• Get institutional and sponsor buy-in to plan from the beginning • Study how/where this has worked well in the past, ideally with quantifiable results

AIM-4	Use focused peer reviews in place of traditional gate reviews - they take time!
Barriers to Adoption	• Legacy processes/culture • Institutional reflexes/cultural norms • Prescriptive proposal calls/risk class
Potential Impact	• Consistent, actionable, timely advice • Reduced redundant docs • Shift reviewers from a compliance-focused RFA role toward active problem-solving as co-solvers
Implemen-tation	• Institutional/sponsor buy-in on deviating from traditional gate reviews in favor of streamlined peer reviews • Just do it!

[3] Cost, Schedule, & Risk Philosophy

AIM-5	**Establish criteria for building multiple instrument copies to reduce cost and schedule**
Barriers to Adoption	● Funding mechanism ● Coordinating buys across programs/projects/institutions is complex and requires a common strategic framework
Potential Impact	● Increased science for lower cost when considering the full NASA science portfolio
Implemen-tation	● PI can buy spares from reserves ● Building multiples from the get-go ● Keep multiple builds in mind when designing

AIM-6	**Align risk posture with mission objectives and prioritize schedule over full requirement closure**
Barriers to Adoption	● Sponsor related risk ● Institutional inertia
Potential Impact	● Being able to tap in more opportunities ● Programs should not be canceled because of mission failures
Implemen-tation	● Conversation and expectation setting with sponsor early on about cost/risk/schedule ● New analytical model on cost/risk/schedule

[4] New Age Tools & AI

AIM-7	Provide open data and shared development sandboxes across all mission phases
Barriers to Adoption	● Risks of losing IP ● Fear of new tool ● Fear of losing job ● Fear of security ● Training pipeline ● Ethical issues of implementation ● Increase immediate cost
Potential Impact	● Encourages creativity from technical/management/financial stakeholders ● Reduces risk and cost of testing and adopting AI tools ● Creating new ways and new structures to significantly improve the efficiency ● Lowers cost of creating project documentation
Implemen-tation	● Conversation space for exploring ideas/provide safe sandboxes and open, benchmarked datasets for use across mission phases ● Develop metrics for evaluating tools ● Assess long term impact

AIM-8	Balance long-term risks, benefits, and security
Barriers to Adoption	● Competition ● Uncertainty around long-term security, IP, and operational risks
Potential Impact	● Increased efficiency and numbers of low cost missions ● Enables broader AI adoption while limiting downstream risk
Implemen-tation	● Licence close loop models ● Regulate long-term risks, benefits, and security

[5] Interfaces & Standardization

AIM-9	Standardize instrument interface requirements and documentation
Barriers to Adoption	• No standard currently exists • Instruments are spacecraft-specific • Existing companies follow different standards that their revenue and products/services are already based on
Potential Impact	• Instruments cheaper (maybe) and faster available • Instruments can move across multiple spacecraft • More investible • Instruments can jump on flight opportunity that comes up with short mission lead time • Budget is more predictable • Some companies may be pushed out if their model/products uses a different standard
Implemen-tation	• Standard itself can be flexible or tiered • Standard doesn't need to be 100% of every detail (priorities are power, thermal, data) to be a benefit • Distinguish between reference docs and hard requirements

AIM-10	Develop simpler, lower-cost, scalable instruments and standardize architectures for broad use and reuse
Barriers to Adoption	• ROI unclear • Mission funding may not be set up for flexible multi-use instruments • Customer is not interested in funding an instrument more more use cases
Potential Impact	• Can use instruments across multiple missions • Minimize NRE for future instrument development • Mitigation of bus provider going out of business
Implemen-tation	• Identify "investible" instrument/subcomponents cases and target these instances

[6] Requirements & Mission Definition

AIM-11	Enable requirements to flow bidirectionally between science objectives and mission capabilities
Barriers to Adoption	● Requirements typically flow one way, from science to engineering; timelines also make it difficult to account for changes in people, launch opportunities, technology, and processes. ● STM inertia/culture is left-to-right (fear of losing science) ● Mission selection criteria in most AOs grade against this
Potential Impact	● Better manages tradeoffs between science and engineering and allows missions to take advantage of changes in technology and opportunities throughout the mission lifecycle. ● Earlier de-scopes, cheaper missions ● Build to capability rather than bespoke ● Less chance of cancellation ● Remaining within cost-cap
Implemen-tation	● Incentivize build-to-print instrumentation ● Incentivize novel capability usage (e.g., Starlink instead of TDRS) which improves overall program ● Allow the flow of requirement derivation to be bi-directional, looking at different tensions and goals across science and engineering

AIM-12	Define mission success to recognize partial achievement of science and technical objectives
Barriers to Adoption	● Tension between science-first and capability-enhancement ● Mission success is often tied to meeting every level-1 science requirement, with limited room to trade science requirements against technical risk, cost, budget, and engineering objectives.
Potential Impact	● Technology development can assist overall program (incentivizes) ● Allows more technical risk and technology demonstrations while recognizing the difference between flight success and program success. ● Accelerates modernization ● Less risk to programs
Implemen-tation	● Sponsor acceptance and road changes of cultural definition of "success" ● Success is different than meeting "every level-1" ● Allow for partial satisfaction, including technical requirements, to count toward/as mission success.

[7] Verification & Test Approaches

AIM-13	Automate testing process to reduce time, cost, and manual effort
Barriers to Adoption	● Potential upfront costs and time ● Potentially complicating the existing process initially
Potential Impact	● Downstream cost reduction if building multiple systems
Implemen-tation	● Utilise AI for writing test automation scripts ● Incorporate thinking about automated testing in design phase

AIM-14	Allow builders to define risk-based test plans and design for testability
Barriers to Adoption	● Established industry/NASA practices and testing milestones ● Mismatch in testing culture between different actors
Potential Impact	● Reducing total cost of testing down to absolutely necessary tests
Implemen-tation	● Leverage experienced practitioners who have successfully executed this approach over many years ● Transfer that expertise to the broader team through direct mentorship, training, and hands-on guidance

[8] Procurement & Parts

AIM-15	Maximize the use of commercial off-the-shelf (COTS) electronics
Barriers to Adoption	• Trust in parts (risk acceptance) • Some parts may fail and thus cost more overall • Parts that don't meet exactly the requirements are ruled out when in practice could be ok
Potential Impact	• Cost savings • Up-to-date tech • Speed of adoption/procurement • Greater awareness of available standards
Implemen-tation	• Build trust (e.g., Parts Evaluation Acceptance Lab - PEAL) • Accept different risk posture • Work with commercial partners to get radiation standards well-known

AIM-16	Use bulk procurement to reduce cost, long-lead times, and availability constraints
Barriers to Adoption	• Common inventory management • Especially between institutions
Potential Impact	• Lower procurement cost • Established heritage • Remove long-lead schedule (likely preventing schedule overruns)
Implemen-tation	• NASA agency-level purchase of parts to use across multiple programs - and have bulk-buy

[9] Reviews & Documentation

AIM-17	Structure reviews to add project value while maintaining execution pace
Barriers to Adoption	● Culture, inertia ● Fear of mission failure ● Gate reviews incentivize hiding issues
Potential Impact	● Higher productivity of team ● Better more accurate schedules ● Could be higher risk if fewer reviews
Implemen-tation	● Standing peer reviews vs formal gate reviews ● Let the project choose review cadence/structure ● Review structure should reflect risk posture ● Use AI tools where productive ● Reviews should be for collaborating on issues, not success theater ● Cut reviews that are OBE

AIM-18	Streamline decision-making to accelerate mission execution
Barriers to Adoption	● Traditional program management structure distributes ownership/accountability/decision making
Potential Impact	● More effective program management ● Accelerated iteration cycles
Implemen-tation	● Set up reviews so that discussion is quickly actionable ● Fewer decision makers, extreme ownership of PMs/PIs

4. Enabling Science Discovery Through a Lower-Cost, Higher-Cadence Mission Model

A lower-cost, higher-cadence mission model expands how space science can be pursued and requires the science ecosystem to evolve with it. Standardized and commercial capabilities, smaller and sequential missions, non-traditional funding and partnership models, and closer integration of science and engineering create additional pathways for discovery. Realizing their full value requires aligning scientific ambition with mission scale and risk, strengthening pathways from technology development to flight, and broadening how missions are formulated, funded, and implemented.

Higher mission cadence expands scientific return through more opportunities to observe, iterate, and learn. More missions provide more measurements, faster iteration, and greater observation opportunities. Rideshares with exploration missions and lunar transportation infrastructure reduce transportation, ΔV, and communications needs, while constellations and hosted payloads enable multipoint observations with spatial and temporal resolution unavailable from individual spacecraft. Non-traditional funding and partnerships create additional opportunities by aligning science with commercial, operational, defense, philanthropic, or other sources of value, including dual-use applications. Heritage instruments, experienced teams and partnerships, and historical datasets further support focused science, precursor missions, and faster progression toward larger missions.

Standardization, common architectures, and block buys create economies of scale and increase mission agility. Standardized interfaces, spacecraft buses, instrumentation, COTS components, and commercial services reduce recurring cost and enable replication across missions. Block purchases of spacecraft, instruments, components, or other common hardware can further reduce unit cost, secure availability, and shorten long-lead procurement, reinforcing AIM-16. These approaches also enable more organizations to fly missions and respond to short-duration funding and flight opportunities. Planetary missions to unexplored destinations remain more difficult to scale because they often require unique capabilities, although systems proven at nearer, better-understood destinations can provide a foundation for more ambitious targets. Large constellations still require strong systems engineering and affordable, reliable spacecraft to realize these economies.

Commoditizing more of the mission lifecycle expands access while requiring deliberate management of commercial dependencies. Commercial launch demonstrates the cost and access benefits of a service-based model, as well as the continuity and availability risks created when critical capabilities depend on a limited number of providers whose products and priorities evolve with market conditions. Transportation, rideshare interfaces, standardized instrumentation, spare capacity on larger transportation systems, communications, data return, and archiving offer similar opportunities. Larger launch systems also relax some low-mass constraints, while commercial capabilities support greater use of COTS hardware and modular combinations of instruments, spacecraft, and landers.

Specialized science and low-TRL instruments require a continuous pathway from development to flight. Standardized and COTS approaches reduce cost but do not address science objectives requiring specialized instrumentation. Development should advance toward TRL 6 in flight-representative configuration, using available interfaces and engaging partners capable of supporting flight from early TRL stages to minimize redesign and accelerate integration. Programs such as H-TIDeS, followed by H-FORT flight opportunities, provide elements of this pathway from technology maturation through demonstration and flight. Lower-cost missions also require focused science objectives that deliver meaningful, publishable results from smaller increments of data.

Higher cadence enables a different balance among scientific ambition, cost, capability, and risk. Frequent Class D and lower-cost missions provide opportunities to adopt risk postures appropriate to mission objectives, including greater tolerance for individual mission failure across a larger portfolio. Clear communication of the scientific value and rationale for that risk remains essential. Scientists, engineers, commercial partners, operators, and funders also need to shape missions together around science objectives, available capabilities, cost, standardization, and sponsor value.

Non-traditional funding and partnerships expand the range of missions that become viable. Scientific return often creates value over long time horizons and does not always map directly to a conventional revenue model. Missions that also address commercial, operational, defense, societal, or philanthropic objectives can access additional sources of funding and partnership by identifying shared value without diminishing the scientific purpose. These models also require clear approaches to data ownership, access, transparency, and use when missions are not funded exclusively through traditional science programs.

The expanding space ecosystem creates additional ways to connect science expertise with mission execution. Scientists working in industry can serve as **mission scientists**, connecting enabling technologies and implementation with required data products and scientific outcomes. NASA continues to serve multiple roles across the science enterprise, including funding, science leadership, and mission implementation, while competitive principal investigator-led missions, directed missions, commercial partnerships, and mechanisms such as Space Act Agreements provide different models for distributing responsibilities. The opportunity is to match the institutional, partnership, and implementation model to the mission, while maintaining community-driven science priorities and rigorous technical execution.

5. An Evolving Space Science Ecosystem

The space science ecosystem is expanding beyond a single mission, funding, and implementation model. Publicly funded and led science remains foundational, while commercial, philanthropic, academic, and other non-traditional models broaden how science priorities become missions and how missions are funded and implemented.

5.1 The Evolving Role of the Decadal Survey

Decadal surveys benefit from recognizing a broader range of pathways to priority science. Flagships, constellations, smaller missions, and sequential investigations serve distinct and complementary roles. While some major science questions require flagship scale and capability, certain investigations are well suited to smaller or sequential missions that progressively build knowledge and capability. Greater recognition of these approaches, with agile and unified pathways across disciplines, broadens the architectures available to address decadal priorities and enables multidisciplinary and opportunistic science.

5.2 The Evolving Role of NASA

NASA remains foundational to space science, but the ecosystem is evolving and expanding the options for funding and implementation. NASA leads, funds, and conducts science missions, while its Centers, commercial providers, universities, PI-led teams, and privately funded organizations offer different capabilities, operating models, and risk postures. Matching these roles to mission needs expands implementation options while supporting NASA's role in advancing science for broad public benefit.

Commercial and privately funded missions expand access while introducing new dependencies and governance needs. Commercial launch demonstrates both the cost and access benefits of market-driven services and the risks associated with provider availability, continuity, and changing commercial priorities. Similar considerations apply to transportation, communications, hosted payloads, and data services. Non-government deep-space missions also require clear regulatory, planetary protection, and national security frameworks, along with approaches to scientific data access and long-term stewardship. NASA's data archives provide a strong model for preserving broad access to scientific data.

Expanding privately funded science depends on connecting scientific value with private-sector objectives. Private support for science has deep historical precedent, including Bell Labs, where fundamental research and institutional objectives produced major advances. Aligning space science and enabling technologies with commercial, operational, philanthropic, or strategic priorities creates shared value that supports sustained private investment, while government funding remains essential for science with broad or long-term benefits that lack a direct customer or near-term financial return.

6. Conclusion

A new era of space science is increasingly within reach, one defined by a broader portfolio of lower-cost, higher-cadence missions alongside larger missions and flagships. Advances in commercial capabilities, small spacecraft, technology, funding and partnership models, and access to space create new pathways for scientific discovery. Realizing this opportunity requires more than reducing the cost of today's mission model. It requires a mission model designed for affordability, speed, focused science, and execution from the outset.

The next step is translating established lessons into execution. A decade of studies and mission experience has identified many of the practices that reduce cost and improve efficiency. Meaningful progress depends on applying those lessons through changes in how missions are formulated, funded, developed, and executed.

Affordable missions require a different operating model from the outset. Science objectives and engineering capabilities evolve together, shaped by multidisciplinary teams, available technologies and interfaces, flight opportunities, funding, and shared value among mission partners. Processes developed over decades to reduce mission risk remain valuable, but their application must be tailored to the cost, schedule, objectives, and risk posture of lower-cost missions - some opportunities may benefit from building up rather than attempting to cut down.

More frequent and diverse access to space creates an opportunity to design missions around available pathways to flight. Rideshares, hosted payloads, commercial transportation, and missions to the Moon, Mars, and beyond support rapid, focused investigations, while specialized science and low-TRL instruments require deliberate pathways to flight readiness. Building toward TRL 6 in flight-representative configurations, using available interfaces, and engaging flight partners early reduces redesign and positions missions to capitalize on time-sensitive opportunities.

New architectures and technologies also reduce the cost of returning science. Onboard processing, including AI/ML, reduces downlink demands by prioritizing data and returning higher-level science products, while distributed spacecraft enable focused observations across multiple locations without concentrating every objective in a single platform.

Small spacecraft provide a mature, complementary pathway for scientific discovery. Their impact in Earth applications, combined with expanding transportation to the Moon, Mars, and beyond, provides a foundation for broader use in space science. The opportunity is not to replace flagships, but to expand the portfolio with lower-cost, higher-cadence missions that pursue focused science, build capability, and create more pathways to discovery.

Annex 1 - Symposium Agenda

Day 1, Tuesday July 28, 2026 Keck Center - Think Tank, Room 155, Caltech		
Time	**Event**	**Speaker**
8:30 - 9:00	Coffee and Refreshments	
9:00 - 9:30	Workshop Logistics and Introduction to KISS	Harriet Brettle
9:30 - 10:15	Participant Introductions	Harriet Brettle
10:15 - 10:30	Study vision and goals for this symposium	Team Leads
10:30 - 11:00	Break	
11:00 - 11:30	Finalize symposium vision and goals via plenary discussion	Mark McElroy
11:30 - 12:00	Science in Focus - plenary discussion	Sona Hosseini
12:00 - 1:30	Lunch at the Athenaeum	
1:30 - 2:30	Plenary discussion - deliverables planning	Andy Klesh
2:30 - 2:50	Lightning Talks 1. Requirements management for launch flexibility - Julianna Scheiman (SpaceX) 2. Intro to Brinson Hub and Hub Approach to Missions - Kat Park (Brinson Exploration Hub, Caltech) 3. NASA roadmap for low cost missions - Carolyn Mercer (NASA HQ) 4. Science and VC - Charles Beyrouthy (Forma Prime)	Julianna Scheiman Kat Park Carolyn Mercer Charles Beyrouthy
2:50 - 3:00	Intro to Breakout Sessions	Harriet Brettle
3:00 - 3:30	Break	
3:30 - 4:45	Breakout Session 1 - Planning - Programmatic Incentives & Business Models - Teams & Teaming - Cost, Schedule, & Risk Philosophy	All
4:45 - 5:15	Report out from Breakout Sessions	All
5:15 - 6:00	Day 1 Debrief - Deliverables Kick Off	Team Leads
6:00	Dinner at the Keck Center	

Wednesday July 29, 2026 - Keck Center - Think Tank, Room 155		
Time	**Event**	**Speaker**
8:00 - 8:30	Institute Opens - FREE THINK TIME	
8:30 - 9:00	Coffee and Refreshments at Keck Center	
9:00 - 9:10	Logistics and Team Lead Goals for the Day	Harriet Brettle and Team Leads
9:10 - 9:30	Lightning Talks - University Small Missions - Jamie Cutler (U Michigan) - Novel orbit configuration used by the ESCAPADE mission - Gwen Hanley (UC Berkeley) - Lunar Trailblazer - Andy Klesh (Brinson Exploration Hub) - Muon Space as a Service - Max Roberts (Muon Space)	Jamie Cutler Gwen Hanley Andy Klesh Max Roberts
9:30 - 10:30	Breakout Session 2 - System Engineering - New Age Tools and AI - Interfaces & Standardization - Requirements & Mission Definition	All
10:30 - 11:00	Break	
11:00 - 11:30	Report out from Breakout Sessions	Groups
11:30 - 12:00	Group Pulse: Accomplishments and Areas Requiring Further Attention	
12:00 - 12:30	Plenary Discussion	All
12:30 - 2:00	Group Picture and Lunch at the Keck Center	
1:45 - 2:50	Thinking outside the box - Mission Planning	Groups
2:50 - 3:20	Lightning Pitches for Lunar/Mars Missions x 12	Team Leads
3:20 - 3:50	Break	
3:50 - 4:10	Plenary Discussion	All
4:10 - 5:00	Breakout Session 3 - Execution - Verification & Test Approaches - Procurement and Parts - Reviews & Documentation	Groups
5:00 - 5:30	Report out from Breakout Sessions	All
5:30 - 6:00	Walk over to the Athenaeum	All
6:00	Dinner at the Athenaeum	

Keck Institute for Space Studies

Thursday July 30, 2026 - Keck Center - Think Tank, Room 155		
8:00 - 8:30	Institute Opens - FREE THINK TIME	
8:30 - 9:00	Coffee and Refreshments at Keck Center	
9:00 - 9:15	Logistics and Team Lead Goals for the Day	Harriet Brettle and Team Leads
9:15 - 9:45	Lightning Talks - Access Starlink connectivity for spacecraft - Caitlin Smith (SpaceX) - Autonomy and Simulation as Cost Levers for Moon/Mars Missions - Giusy Falcone (U Michigan) - Intuitive Machines - Ben Bussey (Intuitive Machines) - Relativity Mars Mission Update - Don Banfield (NASA Ames) - Lessons learned from engineering practice - Jacob Clarke (SDL)	Caitlin Smith Giusy Falcone Ben Bussey Don Banfield Jacob Clarke
9:45 - 10:30	Plenary Discussion: Paradigm Shifting Ideas Review and Report Next Steps	Team Leads
10:30 - 11:00	Break	
11:00 - 11:30	Round Table - Personal Actions	All
11:30 - 12:00	Symposium Closeout	Harriet Brettle
12:00 - 1:30	Lunch at the Keck Center	
1:30 - 2:30	Optional Afternoon Session - Brinson Exploration Hub Tour	All
5:00	Institute Closes	

Annex 2 - Initial list of AIMs

Affordability Improvement Measure (AIM)	Category
Structure orgs such that a mission failure does not jeopardize future missions	Programmatic Incentives and Business Models
Leverage commercial mission service providers and science-as-a-service delivery models	Programmatic Incentives and Business Models
Use fixed-price contracting	Programmatic Incentives and Business Models
Incentivise lower costs in mission planning, development, and execution	Programmatic Incentives and Business Models
Increase financial incentives for scalable multi-flight mission development	Programmatic Incentives and Business Models
Restructure NASA AO/science calls to enable low-cost missions	Programmatic Incentives and Business Models
Avoid legacy institutions constrained by risk-averse practices and scrutiny	Programmatic Incentives and Business Models
Adopt on-call model	Teams and Teaming
Use small multi-role teams and independent assessments	Teams and Teaming
Reduce management layers; Increase PI autonomy in decision making	Teams and Teaming
Use minimal operations team (Apply to subsystem & system levels)	Teams and Teaming
Independent cross-team validation	Teams and Teaming
Co-locate engineering teams	Teams and Teaming
Tighten culture between spacecraft builders, science users, and financers	Teams and Teaming
Develop missions collaboratively via guidance from global network of innovation hubs	Teams and Teaming
Accept higher mission risk and prioritize schedule over full requirements closure	Cost, Schedule, and Risk Philosophy
Drive decisions based on delivery date	Cost, Schedule, and Risk Philosophy
Reduce redundancy	Cost, Schedule, and Risk Philosophy

Affordability Improvement Measure (AIM)	Category
Reduce technical margins, correction reserves, and power system redundancy	Cost, Schedule, and Risk Philosophy
Use risk-informed cost targeting instead of requirement-driven mitigation	Cost, Schedule, and Risk Philosophy
Relax optical alignment tolerances; Relax structural alignment tolerances; Use shimming instead of precision machining	Cost, Schedule, and Risk Philosophy
Relax risk posture for non-critical systems	Cost, Schedule, and Risk Philosophy
Defer software completion into integration phase	Cost, Schedule, and Risk Philosophy
Reduce DSN contact duration	Cost, Schedule, and Risk Philosophy
Emulate successful low cost instances from the past	Cost, Schedule, and Risk Philosophy
Overlap subsystem design; Overlap design & analysis; Simultaneous reviews; Concurrent iterations; Use concurrent design processes	Cost, Schedule, and Risk Philosophy
Automate operations	New Age Tools and AI
Automate fault recovery; Increase onboard decision-making; Use rule-based autonomy	New Age Tools and AI
Shared models/tools	New Age Tools and AI
Adopt model-based systems engineering	New Age Tools and AI
Leverage AI for project management	New Age Tools and AI
Leverage AI for mission operations	New Age Tools and AI
Separate spacecraft and instrument development	Interfaces and Standardization
Standardize spacecraft buses, interfaces, and modular subsystem integration	Interfaces and Standardization
Use constellation-level operations; Enable multi-mission parallel operations	Interfaces and Standardization
Use rideshare instead of dedicated launch	Interfaces and Standardization
Verify unit consistency across all interfaces; Add interface audits; Add automated interface checks	Interfaces and Standardization
Enforce ICD ownership and signoff; Disallow implicit	Interfaces and

Affordability Improvement Measure (AIM)	Category
assumptions; Validate data formats and ranges	Standardization
Make instruments scalable for repeat/similar missions; Use shared infrastructure	Interfaces and Standardization
More agile and narrowly scoped mission formulation; Target the science goals that are most affordable	Requirements and Mission Definition
Minimize number of requirements	Requirements and Mission Definition
Dynamic requirements windows	Requirements and Mission Definition
Use performance-based requirements only	Requirements and Mission Definition
Allow 'flow-up' requirement derivation	Requirements and Mission Definition
Validate transient sensor behavior; Add debounce/filtering; Prevent false positives	Verification and Test Approaches
Use protoflight testing instead of full qualification	Verification and Test Approaches
Build flight model before engineering model	Verification and Test Approaches
Develop EM and FM in parallel	Verification and Test Approaches
Reduce verification testing	Verification and Test Approaches
Reduce environmental test cycles and durations using heritage justification	Verification and Test Approaches
Reduce integration steps; Combine subsystem integrations; Reduce mate/demate cycles	Verification and Test Approaches
Test edge-case triggers in sensors	Verification and Test Approaches
Replace tests with analysis	Verification and Test Approaches
Lower qualification levels	Verification and Test Approaches
Shift verification from performance to functional	Verification and Test Approaches
Waive subsystem-level environmental testing	Verification and Test

Affordability Improvement Measure (AIM)	Category
	Approaches
Fully or partially eliminate EM	Verification and Test Approaches
Adopt COTS components and commercial capabilities; Use commercial CPU, DRAM/Flash, radios, and other electronics	Procurement and Parts
Accept lower TRL components via commercial adoption	Procurement and Parts
Assign integration responsibility to vendor	Procurement and Parts
Avoid rad-hard processors; Use high-volume legacy parts	Procurement and Parts
Include lessons learned or other guidance in mission development	Reviews and Documentation
Replace full lifecycle reviews with 3–4 tailored reviews	Reviews and Documentation
Use simplified non-standard WBS	Reviews and Documentation
Reduce required documentation set	Reviews and Documentation
Eliminate Standing Review Board (SRB)	Reviews and Documentation
Use weekly cost monitoring instead of full EVM	Reviews and Documentation

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Annex 3 - Acronyms

AI: Artificial Intelligence
AIM: Affordability Improvement Measure
AO: Announcement of Opportunity
CLPS: Commercial Lunar Payload Services
COTS: Commercial Off-the-Shelf
EAR: Export Administration Regulations
ICD: Interface Control Document
IP: Intellectual Property
ITAR: International Traffic in Arms Regulations
KISS: Keck Institute for Space Studies
ML: Machine Learning
NRE: Non-Recurring Engineering
OBE: Overcome by Events
PEAL: Parts Evaluation Acceptance Lab
PI: Principal Investigator
PM: Project Manager
RFA: Request for Action
ROI: Return on Investment
STM: Science Traceability Matrix
T&C: Terms & Conditions
TDRS: Tracking and Data Relay Satellite System
TRL: Technology Readiness Level