EXPLORESCIENCE

NASA, Kick-off Presentation

Solar and Space Physics (Heliophysics) Decadal Survey

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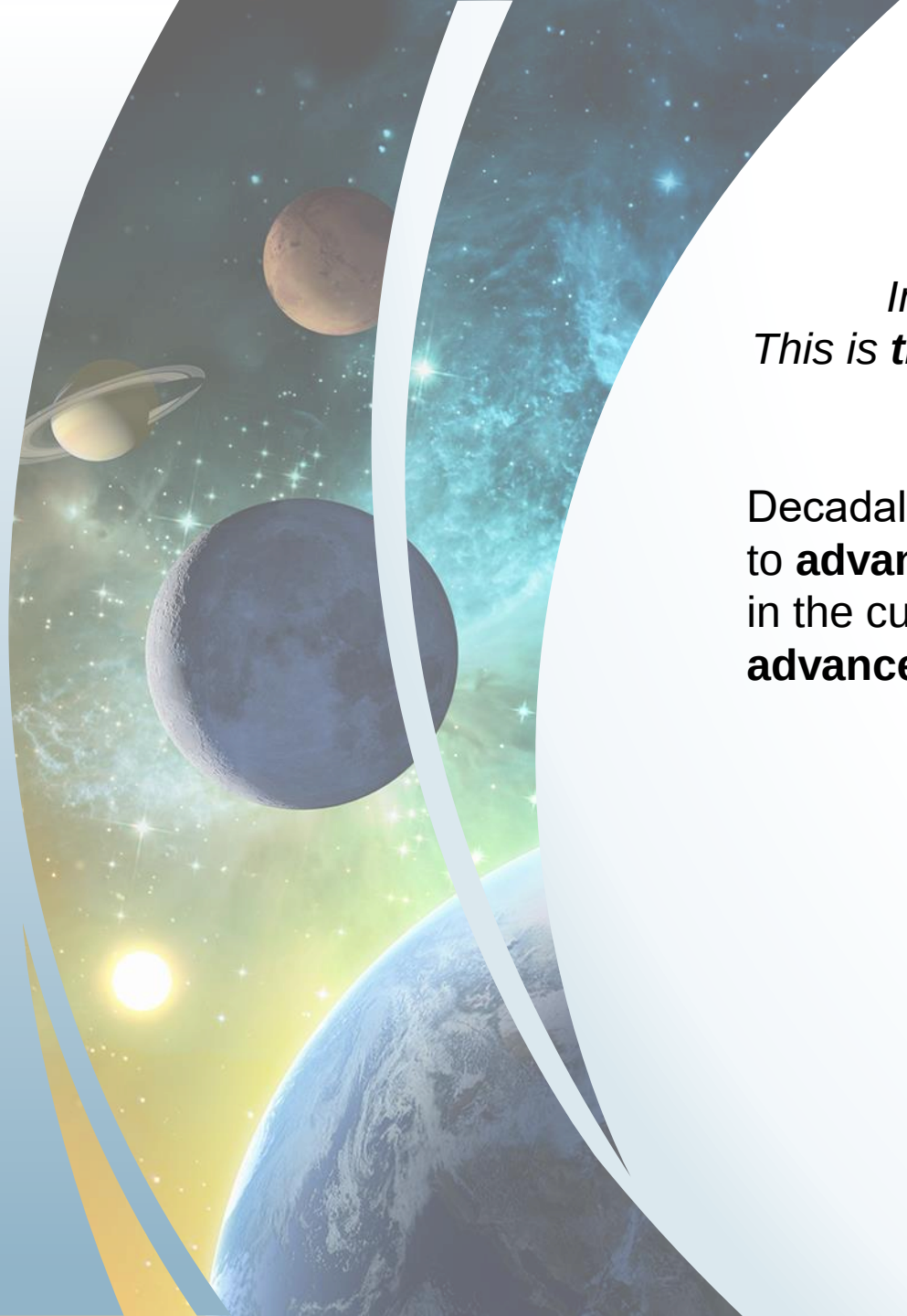
Science Mission Directorate



Decadal Survey

Importance of the Decadal Survey cannot be overstated
*This is **the** opportunity to set a vision for the next decade and beyond!*

Decadal Survey is charged to “generate consensus recommendations to **advance and expand the frontiers of solar and space physics** in the current decade and **lay the groundwork for continued advances in future decades**.” [Decadal Survey, Statement of Task]

We can do bold things,
and this is the Decadal for them

Ambitious but Realistic

NASA is seeking an ambitious but realistic science strategy

What is an ambitious strategy?

An ambitious strategy does not take the next step on the current path, it blazes a new path

What is a realistic strategy? Where does budget factor in?

A strategy defines objectives that can be realistically achieved, but does not prescribe a specific implementation

A strategy must provide flexibility for NASA to respond to emerging realities and possibilities, and must include decision rules that can inform programmatic actions

An ambitious strategy often requires an enhanced budget,
but an ambitious budget alone does not make a strategy ambitious

Enduring Value of Decadal Surveys

"Decadal Surveys are the most prominent and influential activity of the Space Studies Board (SSB) of the National Academies of Sciences, Engineering, and Medicine."
– *The Space Science Decadal Surveys: Lessons Learned and Best Practices* [2015]

Decadal Surveys are central to NASA Science Mission Directorate (SMD) science strategies

- NASA Authorization Act(s) state that the NASA Administrator should set science priorities informed by guidance provided by the Decadal Surveys
- NASA Science Plan(s) identify Decadal Surveys as informing scientific priorities for future NASA science activities

Stakeholders see weight of decadal survey, strength as a *single, coherent document*

- Provides the scientific basis for an Agency strategy
- Plans for the next decade, lays the groundwork for the decade(s) beyond
- Identifies cost-effective investigations to implement the strategy
- Provides community insights to inform programmatic decisions

Heliophysics Science

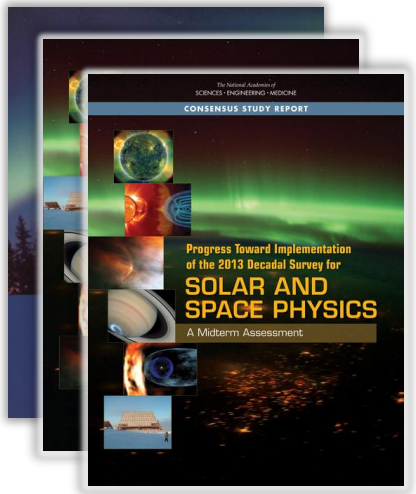
Scope of Heliophysics is Vast…and Growing!

- Heliophysics science contains three key components
  - Historical scope of the field (e.g. solar physics, Sun-Earth connection)
  - New and emerging topics (e.g. astrospheres, exoplanets, planetary habitability)
  - Operational activities (e.g. space weather pipeline, human exploration)

- Scope has grown significantly in the past 10 years, we expect it will continue to grow
  - New capabilities lead to new discoveries, lead to new capability developments
  - Human exploration is advancing beyond low-Earth orbit
  - Challenges to space-based infrastructure are increasing

- Decadal Survey is asked to provide a strategic basis for the entire field
  - What is the state of the science?
  - What are the highest-priority goals?
  - How do we make measurable progress on those goals?

Expanding the Field, Persistent Vision



…the cross-fertilization between solar physics and astrophysics is bidirectional.

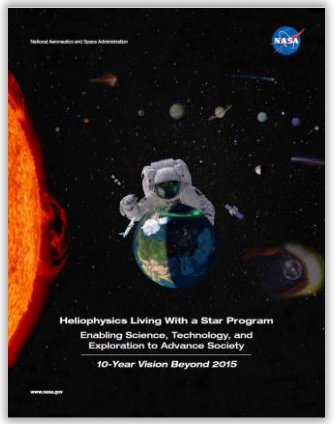
KSG 4 (2013): Discover and characterize fundamental processes that occur both within the heliosphere and throughout the universe.

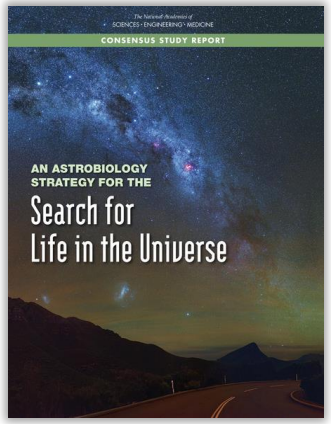
…cross-divisional opportunities for exoplanetary-planetary, astrospheric-heliospheric, solar-stellar, and atmosphere-Earth science research and development of a prioritized strategy for implementing such cross-disciplinary research

…investigate the effects of space weather throughout the solar system, especially at Venus, Earth, and Mars

…investigate the effects of stellar variability on astrospheres and the exoplanets within them

…studies of sun-planet and star-exoplanet connections can improve predictive capabilities

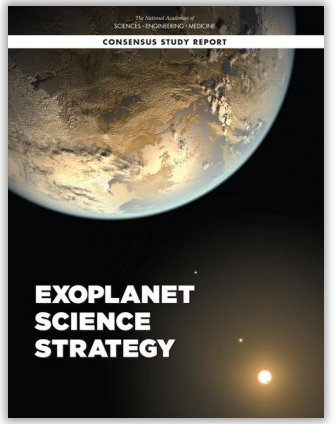




Crossdivisional collaborations […] between Earth science, astronomy, heliophysics, and planetary science have begun the task of breaking down disciplinary entrenchments and are helping the astrobiology and exoplanet communities reach their full potential.

Progress will require […] collaboration between […] stellar astrophysicists, heliophysicists, and statisticians.

The identification of life on an exoplanet will […] only when researchers bring together the combined insights of astrophysicists, planetary scientists, Earth scientists, and heliophysicists…



What will we have accomplished by 2033? What will we be prepared to accomplish by 2050?

Expanding the Field, Recent Activities

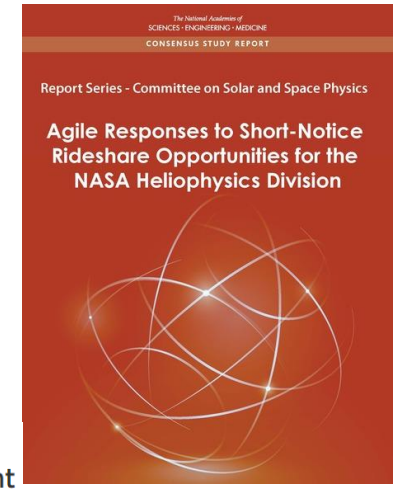
Observations of Extreme ICME Ram Pressure Compressing Mercury's Dayside Magnetosphere to the Surface

Jul 31, 2017

An Earth-like Atmosphere May Not Survive Proxima b's Orbit

HELIOPHYSICS 2050 WORKSHOP

LWS Strategic Science Areas [2019]
- SSA-IX: Solar Impacts on Climate
- SSA-X: Stellar Impacts on Planetary Habitability



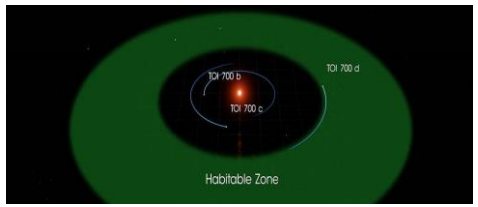
The Space Environment and Atmospheric Joule Heating of the Habitable Zone Exoplanet TOI 700 d

Oct 30, 2020

New Evidence Our Neighborhood in Space Is Stuffed With Hydrogen

Dec 13, 2017

Mars Mission Sheds Light on Habitability of Distant Planets



Oct 8, 2020

A New Look at Sunspots is Helping NASA Scientists Understand Major Flares and Life Around Other Stars

Nov 30, 2018

Charting a Course for Astronaut Safety as NASA Launches to the Moon and to Mars

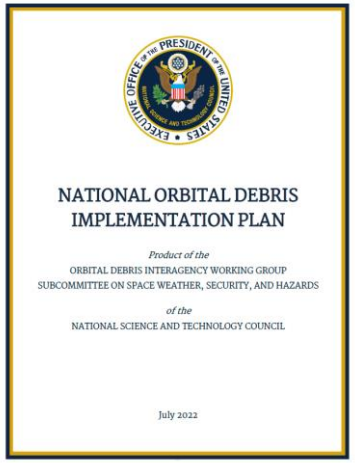
Tonga Eruption Sent Ripples Through Earth's Ionosphere

by truestfreedom — February 5, 2022 in Ripple

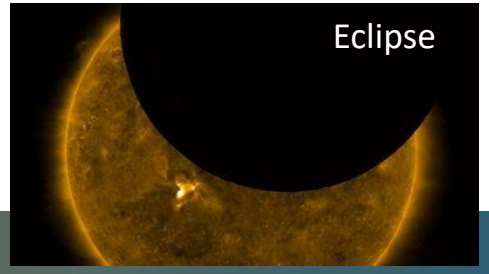
NExSS

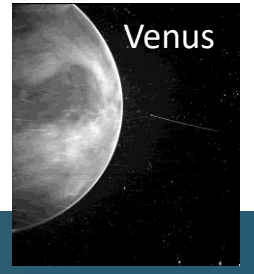
The moon had a magnetic field that helped protect Earth's atmosphere

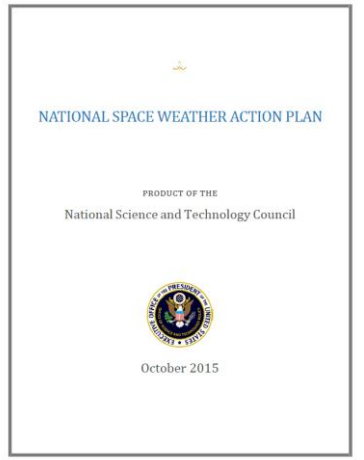
SPACE 14 October 2020



HERMES







Balance in the Science Strategy

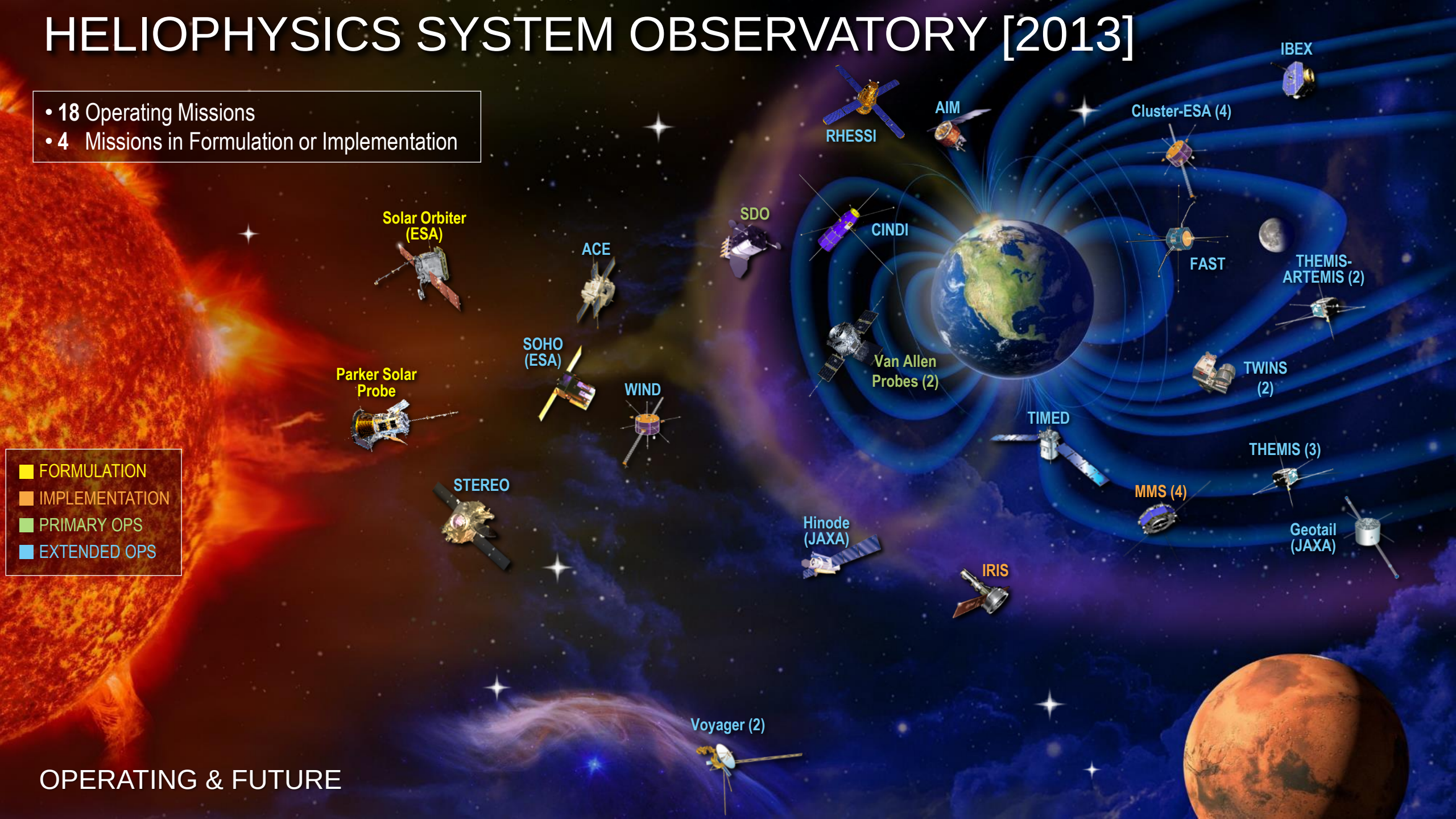
Charge to the Decadal Survey Committee, Study Approach: *In its recommendations, the report should consider the balance of investments for research, facilities, and other projects, based on science area, timing, cost, technical readiness, and other relevant issues.*

- NASA looks to the Decadal Survey for recommendations on balance in the portfolio, including
  - Broad-based advances within the historical scope of heliophysics
  - Focused advances on specific investigations within the historical scope of heliophysics
  - Expansions of the scope of heliophysics to include new and emerging fields
  - Applications of heliophysics science to enable and enhance robotic and human exploration
  - Scientific understanding to inform the transition of space weather capabilities to operational use
- Heliophysics expertise is necessary for scientific success in the new and emerging domains
- As Agency and National priorities turn to these new domains and applications, NASA Heliophysics must proactively engage and be prepared to respond to directives

2013-2023:
Decade of Heliophysics Accomplishments

HELIOPHYSICS SYSTEM OBSERVATORY [2013]

- **18** Operating Missions
- **4** Missions in Formulation or Implementation

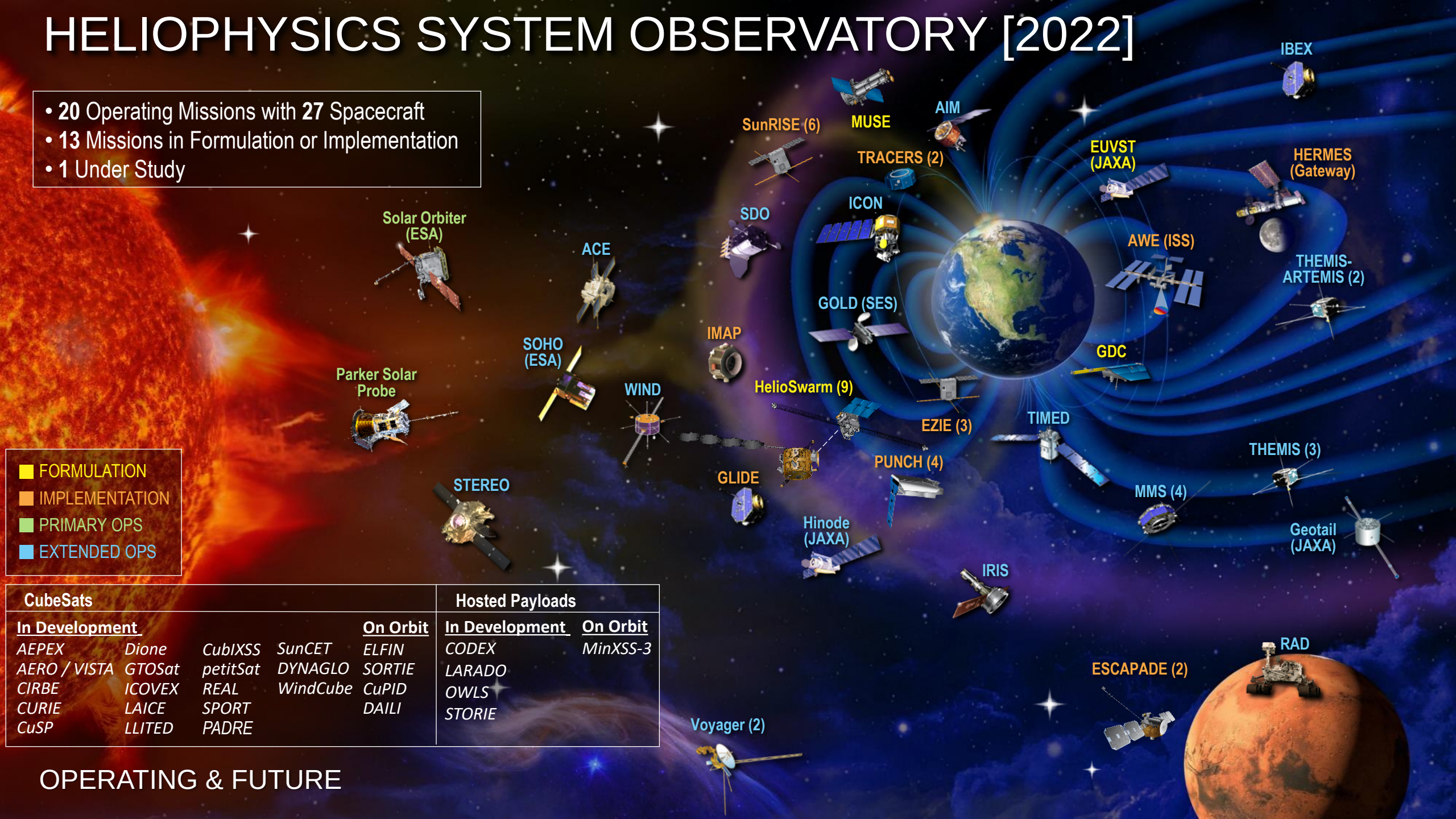


- FORMULATION
- IMPLEMENTATION
- PRIMARY OPS
- EXTENDED OPS

OPERATING & FUTURE

HELIOPHYSICS SYSTEM OBSERVATORY [2022]

- **20** Operating Missions with **27** Spacecraft
- **13** Missions in Formulation or Implementation
- **1** Under Study



- FORMULATION
- IMPLEMENTATION
- PRIMARY OPS
- EXTENDED OPS

CubeSats

In Development

AEPEX
AERO / VISTA
CIRBE
CURIE
CuSP
Dione
GTOSat
ICOVEX
LAICE
LLITED
CubIXSS
petitSat
REAL
SPORT
PADRE
SunCET
DYNAGLO
WindCube

On Orbit

ELFIN
SORTIE
CuPID
DAILI

Hosted Payloads

In Development

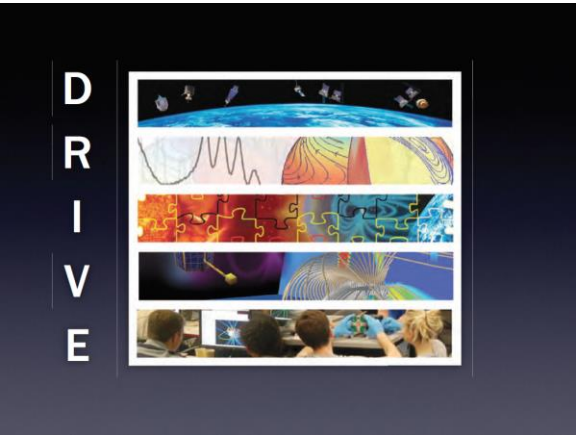
CODEX
LARADO
OWLS
STORIE

On Orbit

MinXSS-3

OPERATING & FUTURE

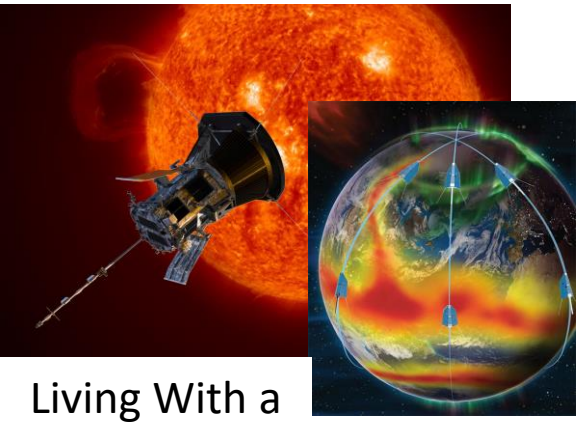
Division Response to the 2013 Decadal Survey



- DRIVE augmentation to R&A
  - DRIVE Science Centers
- HSO, extended mission augmentation
- Support of CubeSats, suborbital projects

- Increase of Explorers cadence
- Combination of MIDEX, SMEX, MOs

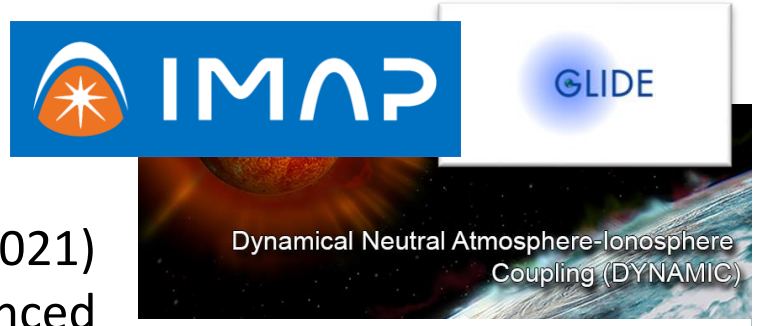
Explorers



Living With a Star

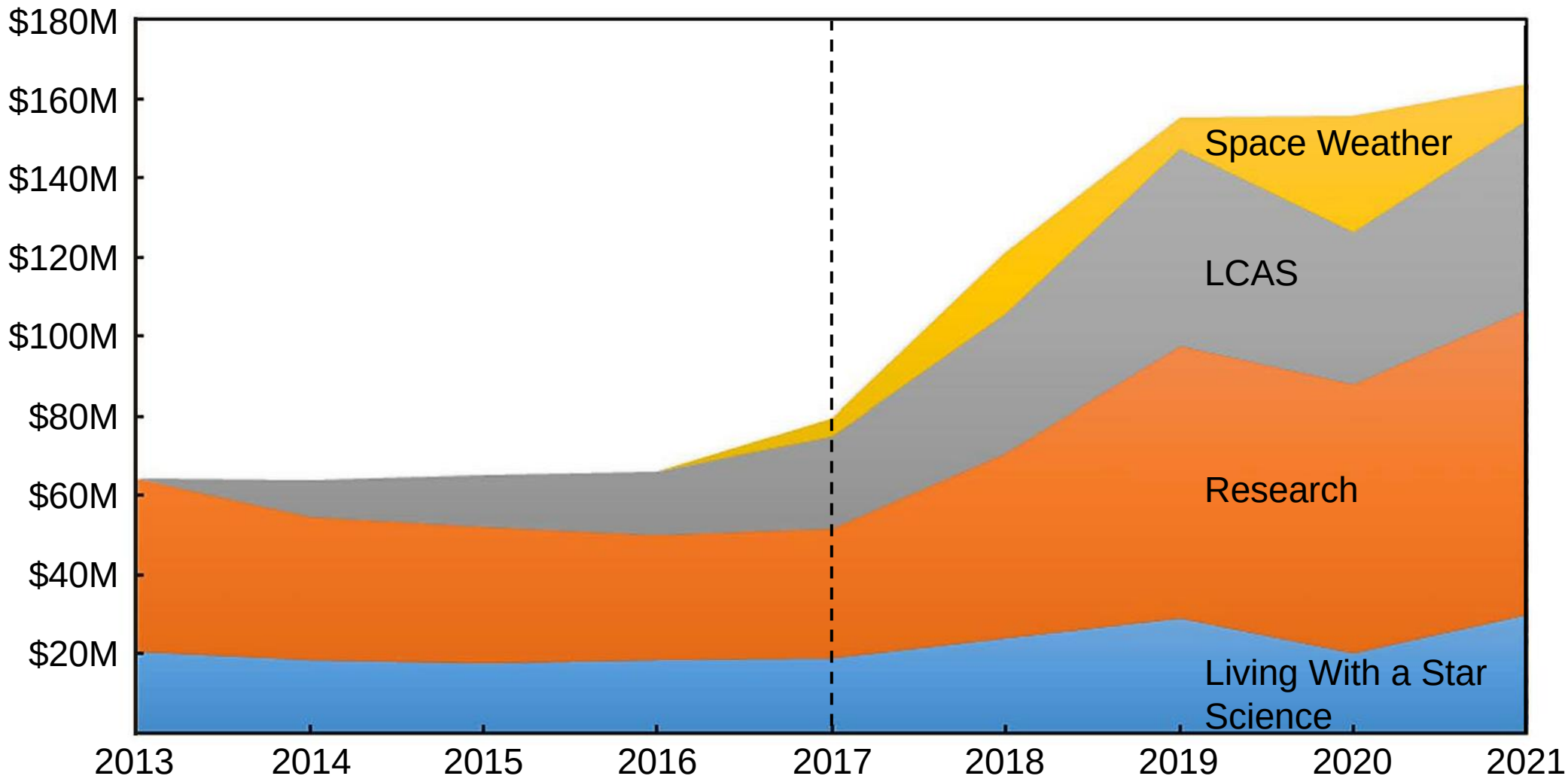
- Parker Solar Probe (mission success criteria met, 2021)
- GDC formulation (investigations selected, 2022)

- IMAP solicitation (confirmed, 2021)
- DYNAMIC pre-formulation announced



Solar Terrestrial Probes

Impact of the Decadal Survey



Program of Record

Program of Record

Program of Record is detailed in a separate document. These slides summarize programs and identify specific requests.

The Program of Record is those activities which will continue as planned through the next decade in the absence of recommendations from the Decadal Survey to make changes.

- NASA has six separate programs supporting heliophysics projects
  - Research
  - Explorers
  - Living With a Star
  - Solar Terrestrial Probes
  - Space Weather
  - Technology

Created since the 2013 Decadal Survey

- NASA invites specific decadal input on
  - Implementation of Decadal Survey-recommended missions
  - Heliophysics System Observatory (HSO), Extended Missions

Implementation of Recommended Missions

Clarified request: *NASA invites the Decadal Survey Committee to provide input on the missions recommended by the 2013 Decadal Survey, with particular emphasis on the innovations that NASA pursued during the formulation stages.*

- *NASA invites the Committee to 1) affirm the continued priority of GDC science, and 2) provide input on NASA's consideration of space weather interests as part of the GDC science mission, including provision of low-latency data products and development of science capabilities that could later be transitioned to operations. Specifically, the latter input is invited to inform future mission formulations where collaborations would realize cross-Agency benefits.*
- *NASA invites the Committee to affirm the continued priority of DYNAMIC science, and to provide input on the formulation of DYNAMIC with a dependence on GDC-provided measurements. This input is invited both for achieving this decadal-level science in a cost-effective manner and to inform future mission formulations that could realize similar benefits.*
- *NASA invites the Committee to provide input on NASA's leveraging of strategic mission launches (e.g. Sun-Earth L1 point, lunar orbit) to enable the formulation of small missions that might not be cost effective outside of a specific, targeted launch opportunity. Specifically, this input is invited to inform future mission formulations that could realize similar benefits or enable science not otherwise cost effective.*

Heliophysics Extended Missions

Charge to the Decadal Survey Committee, Study Approach: *In its recommendations, the report should consider the balance of investments for research, facilities, and other projects, based on science area, timing, cost, technical readiness, and other relevant issues.*

Clarified request: *NASA expects the Decadal Survey to fully discuss scientific and budgetary concerns for heliophysics extended missions in its consideration of balance within the spaceflight mission programs. This includes but is not limited to 1) balancing extended operations with new starts for healthy, sustainable programs, 2) discussing points for programmatic consideration with regards to extended mission termination decisions, and 3) including clear expectations for extended missions in the budget recommendations.*

- Successful projects in the last decade imply larger demands in the next decade
  - >$90M/yr (>12% FY22 budget) in current costs (projects in extended missions now)
  - ~$100M/yr (~13% FY22 budget) in new costs by 2027 (projects currently in dev./prime ops)
- Successful implementation in the next decade requires full consideration of these costs
  - ~$150M/yr in costs by 2034 for 2013 decadal cadences alone (i.e. not including current missions)

Charge to the Decadal Survey Committee

Charge to the Decadal Survey

- Decadal Survey charge is in three documents
  - Statement of Task provides the framework for NASA's charge to the Decadal Survey Committee
  - Study Approach contains additional details and specific requests, for all three agencies and for NASA alone
  - This kick-off briefing and supplemental presentations provide further clarification/specificity to the Statement of Task, Study Approach
- Following slides
  - Emphasize key aspects of the Statement of Task, Study Approach

NASA anticipates and welcomes Committee requests for additional information and discussions

Healthy, Sustainable Mission Programs

- The health and sustainability of a program goes beyond identifying compelling science goals
  - Well-defined science objectives that can be *completed*
    - Completion of science objectives means measured progress on goals
  - Mission scoped to what is necessary to complete the science
  - Range of mission sizes recommended for each program
  - Recommendations do not define implementation, do leave flexibility

- Can not overemphasize the necessity of each program to support a range of mission sizes
  - Recommendations for only large missions creates a challenge to implementation
  - Range of mission sizes permit NASA to optimize the portfolio through the decade

- Each program needs to have clearly defined roles in NASA's support of scientific research
  - Midterm Assessment discussed the 2013 division between STP and LWS, and the Space Weather and Technology programs bring additional distinctions
  - NASA has provided documents with our distinctions, welcomes input on potential optimizations

State of the Profession

- State of the Profession encompasses everything regarding the individuals and communities that do and can participate in heliophysics research
  - Evolving in recent years, continuing to evolve in parallel with the Decadal Survey's work
  - Statement of Task and Study Approach contain details of interest

- *Do not expect* the Decadal Survey to…
  - Offer specific actions, implementations to solve all challenges

- *Do expect* the Decadal Survey to…
  - Identify challenges, concerns
  - Provide background, context for challenges
  - Discuss potential studies that the agencies might consider conducting
    - Study objectives, motivations
    - Metrics, guidelines for metrics
    - Potential pitfalls

Inter-Agency Effort [1]

- National Aeronautics and Space Administration (NASA)
  - National Aeronautics and Space Act of 1958 (Public Law 85–568): To conduct aeronautical and space activities.
    - For the purpose of expansion of human knowledge; improvement of aeronautical and space vehicles; development of vehicles capable of carrying instruments and humans through space; preservation of the role of the United States as a leader in space science and technology.
- National Science Foundation (NSF)
  - National Science Foundation Act of 1950 (Public Law 81-507): To promote the progress of science.
    - For the purpose of advancing the national health, prosperity, and welfare; securing the national defense.
- National Oceanic and Atmospheric Administration (NOAA)
  - Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418)
    - To conduct research on all telecommunications sciences []; preparation and issuance of predictions of electromagnetic wave propagation conditions and warnings of disturbances in such conditions; research and analysis in the general field of telecommunications sciences in support of other Federal agencies

Inter-Agency Effort [2]

- NASA, NSF, and NOAA collaborate on solar and space physics research and projects
  - Space weather pipeline: basic research, applied research, operational activities
  - Decadal survey provides a single strategy, three agencies work together

- Each agency has its own mission, mandates, and scope of responsibility
  - NSF: Basic research
  - NASA: Spaceflight science investigations
  - NOAA: Operational activities

Decadal Survey Statement of Task: *Recommendations regarding operational space weather activities and/or projects shall be directed to only NOAA. Recommendations regarding establishing new or supporting established ground-based observatories shall be directed to only NOAA and NSF, as appropriate. Recommendations regarding spaceflight projects shall be directed to only NOAA and NASA.*

Supplemental Presentations

- NASA has prepared documents with additional information
  - High-level information identified by Mid-term Assessment, Statement of Task package, NASA staff
  - Provide a starting point for Committee deliberations
  - Backup section of this slide deck capture specific requests made in those documents, for Committee's convenience

- For these and other topics, we expect that the Committee will have requests for additional information
  - Happy to provide Division staff for discussions
  - Need specific questions and the motivation behind the request (sometimes what people ask us isn't the real question they have)

2024-2033:
Decade for Heliophysics Growth

#HelioRocks

Supplemental Presentation
Clarified Requests to the Decadal Survey

Artemis

Charge to the Decadal Survey Committee: *NASA invites input on where its research and mission programs can support and leverage Agency human exploration and lunar exploration activities (including but not limited to the Artemis Program). Recommendations on the research strategy should explicitly reference those opportunities, where appropriate.*

- Identify heliophysics and space weather science to be conducted in the next decade that is enabled and enhanced by lunar exploration activities (both in lunar orbit and on the lunar surface)
- Identify preparatory space weather activities to be conducted in the next decade that would enable or enhance human exploration of Mars beginning in the 2030s
- Identify where and how heliophysics and space weather science can inform and later integrate into human exploration architecture implementation, including but not limited to the purposes of
    - Providing needed observing, modeling, and support to operational users for human missions to the Moon and later to Mars
    - Providing a technical foundation for human and robotic exploration implementation decisions
    - Enabling and enhancing heliophysics research in the next decade and beyond (e.g. lunar farside radio telescope with solar observation capability, lunar resupply vehicle put into a heliocentric disposal orbit)
- Identify opportunities for cross-disciplinary and -divisional science activities within lunar exploration activities
- Prioritize within the Heliophysics Division programs activities supporting and leveraging robotic and human exploration of the Moon and Mars
- Clearly incorporate budget guidance for recommended activities

Space Situational Awareness/Orbital Debris

Charge to the Decadal Survey Committee: *The survey should assess to what degree the Heliophysics programs should support Space Situational Awareness/Orbital Debris research and technology. NASA specifically invites input on the scientific and/or programmatic connection(s) with its Space Weather Science Application program.*

- Identify connections between Heliophysics Division and the SSA/OD domain, specifically
  - Programmatic connection(s) between SSA/OD research and the Space Weather Program
  - Potential contributions of heliophysics science to SSA/OD, including potential transitioning of capabilities to operational partners
  - Potential uses of SSA/OD activities to inform and advance heliophysics science
  - Potential collaborations between NASA and other agencies/organizations
- Recommend amount and types of SSA/OD support within the heliophysics research and technology portfolio, including but not limited to
  - Inclusion within the scope of competed research programs
  - Development of SSA/OD-relevant space flight technologies
- Prioritize new SSA/OD-focused mission(s) within the Heliophysics Division programs
- Clearly incorporate budget guidance for recommended SSA/OD activities

Technology

Charge to the Decadal Survey Committee: *NASA recognizes that establishing a long-term strategy requires early investments in a range of technologies and techniques that may open up paths for future scientific endeavors. The survey is encouraged to, as part of a long-term strategy, make recommendations on the early development of technologies and techniques that would enable specific science investigations in and beyond the next decade.*

- Identify technology developments recommended for the next decade
  - Enabling, enhancing technologies for recommended projects
  - Early-stage investments to enable new science beyond the next decade
- Prioritize recommended technology investments, including strategic guidance for the Technology Program
- Prioritize technology demonstration activities, including TDOs and TDMOs
- Clear incorporation of budgetary requirements for investments and projects
  - Including transition of budgetary responsibility to recommended projects during Phase A