

National Aeronautics and
Space Administration



Heliophysics Division

Space Weather Council Kickoff

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March 2, 2022

NASA Space Weather

Space Weather Goal: Advance the science of space weather to empower a technological society safely thriving on Earth and expanding into space.

- NASA plays a vital role in space weather research by providing unique, significant, and exploratory observations and data streams for theory, modeling, and data analysis research, and for operations. SMD/HPD is uniquely poised to support needs of the National and International space weather enterprise and the Agency's Artemis mission.
- Various executive (NSW SAP) and legislative (PROSWIFT Act) mandates direct NASA to address research and application aspects of space weather. Operational agencies have a mandate to fulfill their mission, but NASA has the flexibility to "push the envelope"
- NASA Heliophysics works as the research arm of the nation's space weather effort, coordinating with the U.S. National Oceanic and Atmospheric Administration, the National Science Foundation and the U.S. Geological Survey, and the U.S. Air Force Research Laboratory on the National Space Weather Action Plan.





Goals

- NASA plays a vital role in space weather research by providing unique, significant, and exploratory observations and data streams for theory, modeling, and data analysis research, and for operations.
- NASA's contributions to observing and understanding space weather are critical for the success of the National and International space weather enterprise.
- NASA has a preeminent space weather capability through the pursuit of the following goals:

1. Observe

- Advance observation techniques, technology, and capability

2. Analyze

- Advance research, analysis and modeling capability

3. Predict

- Improve space weather forecast and nowcast capabilities

4. Transition

- Transition capabilities to operational environments

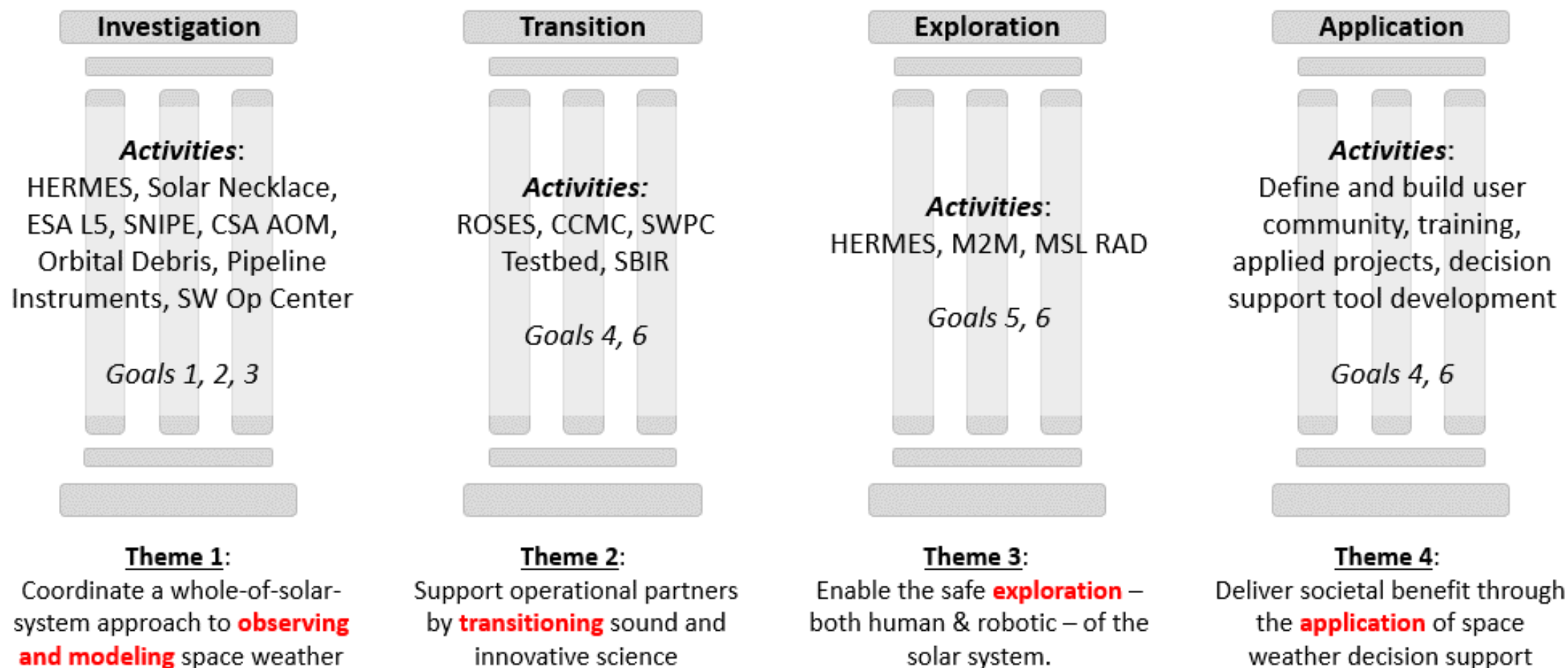
5. Support

- Support Robotic and Human Exploration

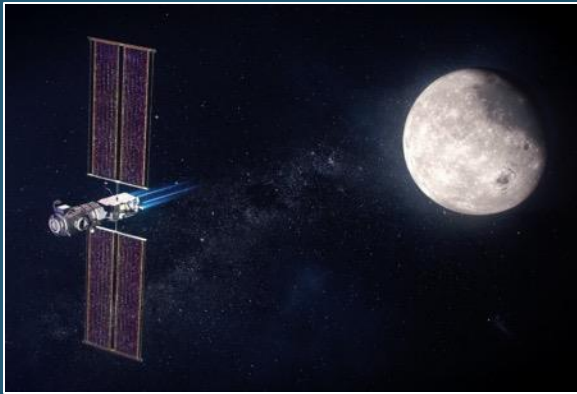
6. Partner

- Meet National, International, and societal needs consistent with Government directives

Space Weather Program Pillars



NASA Space Weather



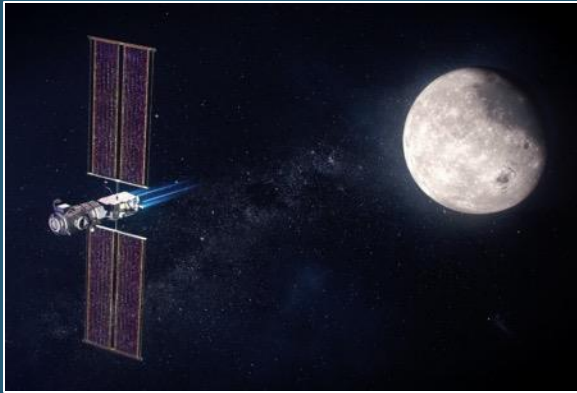
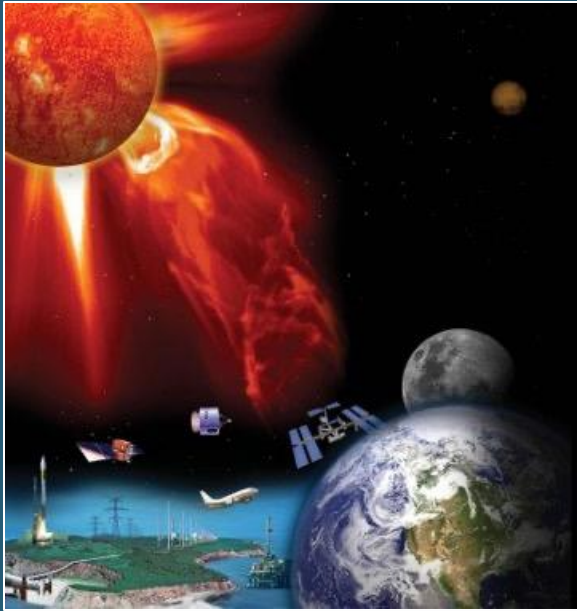
Recent Accomplishments

- NASA space weather strategy and implementation plan
- NOAA and DoD Framework to transition NASA research, techniques and technology relevant to space weather operations
- Joint NSF-NASA Space Weather Quantification of Uncertainty (SWQU) grant solicitation
- Research to Operations to Research (R2O2R) grant solicitation: Additional Transition Step for efforts that show promise to use in an operational space weather environment at NOAA or DoD
- Rapid turnaround HERMES instrument package in support of Gateway and Artemis and space weather; HERMES Inter-Disciplinary Scientists (IDSs) were selected in June 2021
- Completed a much-needed Space Weather Science Gap Analysis – managed by APL - https://science.nasa.gov/science-pink/s3fs-public/atoms/files/GapAnalysisReport_full_final.pdf

NASA Space Weather

Looking Ahead

- Develop space weather instrument pipeline for future opportunities
- Engage international partners on future collaborations (ESA Lagrange, CSA AOM, ESA Daedalus, KASI SNIPE, ISRO Aditya, others?)
- Continue transitioning Radiation Assessment Detector (RAD) instrument on Curiosity rover on Mars from Planetary Science Division to the Heliophysics Division to engage space weather community supporting forecasting research at Mars
- Continued funding R2O2R grants and SWx SBIR efforts - >70 funded efforts with multiagency input (DoD/NOAA/NSF/NASA)
- Preparing solicitation for Space Weather Centers of Excellence – [draft released](#) out for community comment
- PROSWIFT: Actions responding to PROSWIFT Act are well underway (detail in next slides)

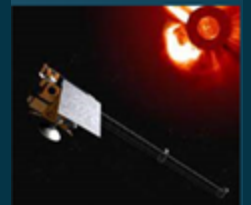


HPD PROSWIFT Actions

PROSWIFT allows NASA to focus on what NASA does best in space weather: Pushing the limits of our understanding the Sun-Earth system including space weather phenomena and leading the evolution of the space-based network of Heliophysics observatories – and the science behind them – through new missions, technology development, and cutting-edge research and modeling.

Steps underway at NASA that are in line with responsibilities delineated in the PROSWIFT act include:

1. Participation in the new **Space Weather Interagency Working Group** established under the National Science and Technology Council; - SWORM
2. Collaborating with NOAA to establish the **Space Weather Advisory Group** for the Interagency Working Group (established) and a **Space Weather Roundtable** at the National Academy of Science (in process)
3. Strengthening our partnership with ESA and other international and interagency partners to ensure maintained operations of the **SOHO/LASCO** satellite, and other space weather monitoring satellites still in operations, including the ACE, DSCOVR, GOES, SDO, STEREO, and Wind observatories to ensure operational contingency plans that provide continuous space weather forecasting in the event of an unexpected SOHO/LASCO failure;
4. Planning for **space weather monitoring capability** on future NASA missions including the Lunar Gateway (HERMES) and Geospace Dynamics Constellation;



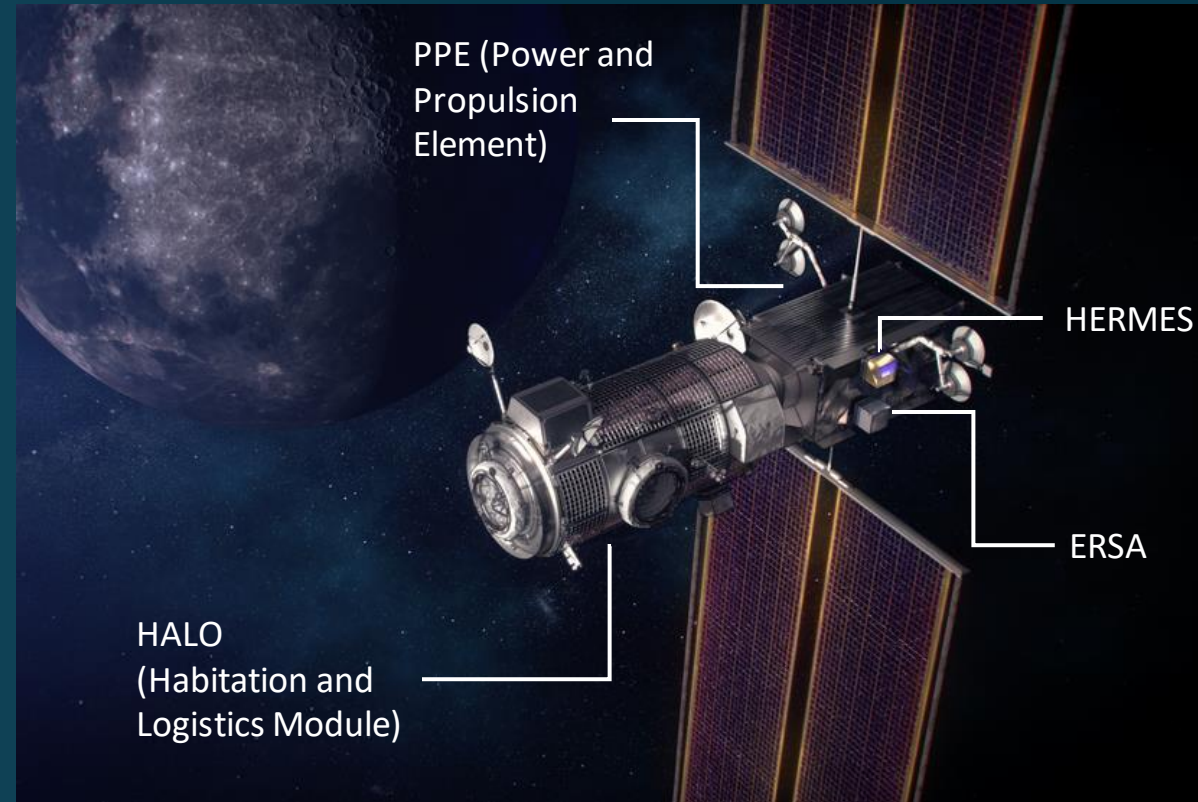


HPD PROSWIFT Actions Cont.

6. Working with other federal agencies including NOAA and DOD to build new space-based monitoring missions, like the NOAA-NASA SWFO-L1 mission (currently in development), to ensure the government has backup capability among our observatories to sufficiently maintain space weather forecasts
7. Carrying out **basic research in solar and space physics**, and space weather, including joint interagency research and modeling solicitations with NSF and NOAA;
8. Developing a **robust partnership with NOAA, NSF, and DOD** with the completion of an **interagency Framework** document that describes the process to transition federally funded space weather research to benefit operational and applied usage, and to ensure that the insights garnered from operations and applications can inform the future direction of NASA-sponsored research
9. Supporting competitively awarded grants for multidisciplinary **Space Weather Centers of Excellence**, for the purpose of advancing solar and space physics and space weather research-to-operations, and which could eventually develop products to be transitioned through the Framework process
10. **Collaborating with international partners** to improve our understanding and advance forecasting for space weather both in the near-earth regions and deep space beyond the protective cocoon of Earth's magnetosphere – (e.g. Artemis/Gateway, Vigil (aka Lagrange). Partners include, ESA, Canada, Japan, Korea, India, and Brazil.

Gateway: HERMES

- The NASA space weather instrument suite, led by HPD, will observe solar particles and the solar wind. The second scientific investigation is a radiation instrument package, built by the European Space Agency.
 - NASA Suite: **HERMES** (Heliophysics Environmental and Radiation Measurement Experiment Suite)
 - ESA Suite: **ERSA** (ESA Radiation Sensors Array)
- **Program Office:** Living With a Star (LWS) Program, Explorers and Heliophysics Projects Division (EHPD), Goddard Space Flight Center (GSFC)
- This payload will enable meaningful science, support Artemis, and be forward looking to crewed missions to Mars.



Achieving the Science

Six Competitively-Selected Interdisciplinary Science (IDS) Teams will work with the HERMES Instrument Teams to

- Develop advanced data products
- Address HERMES Defined Science Objectives
- Address additional objectives defined by the IDS Teams

Teams include international partners

Title	Lead Institution	Team	Goal
Gateway to robust HERMES science: Filling the potholes of non-ideal accommodations on the road to the Moon	U.Michigan	M. Liemohn, N. Gnaushkina, J. Cutler, J. Raines, S. Lepri	C
HEMERA: HERMES Modelling and Enhanced Response Analyses	JPL	I. Jun, P. Caron, W. Kim, J. Mateo-Valez, A. Sicard	C
The Heliospheric Current-Sheet Network and the Cellularization of the Solar Wind	Space Science Institute	J. Borovsky, V. Roytershteyn, A. Greco	A
Understanding, Specification, and Prediction of Lunar Space Weather	Space Hazards Applications	J. Green, J. Likar, L. Parker, D. Turner, C. Keys, D. Pitchford	B
Understanding Ion Composition at Lunar Orbits	NASA GSFC	A. Glocer, L. Chen, J. Dorelli, A. Runov, M. Sarantos, G. Toth, M. Nose	B
Investigations of the Near-Moon Plasma and Magnetic Field Environment with Three-point Measurement by THEMIS ARTEMIS	UCLA	A. Runov, K. Khurana, J. Liu, M. Balikhin	B

Space Weather Research to Operations / Operations to Research (R2O2R)

A yearly element conducted on behalf of NASA, NOAA, and NSF under a tri-agency agreement.

ROSES-22

- Topic(s) will be announced in ROSES-22 amendment – to be released very soon

ROSES-21 (6 selections)

- Solar Flare Forecasts
- Cislunar Space Environment

ROSES-20 (9 selections)

- Ionospheric Disturbances
- Satellite Drag

ROSES-19: (13 selections)

- Open call

New in 2021: R2O2R “Transition Step”

An optional third year to support activities that facilitate transition to operations.

ROSES-18 (8 selections)

- Energetic particles and plasmas in the magnetosphere

ROSES-17 (8 selections)

- Solar wind forecasting

Space Weather Applied Research Challenges (ARCs)

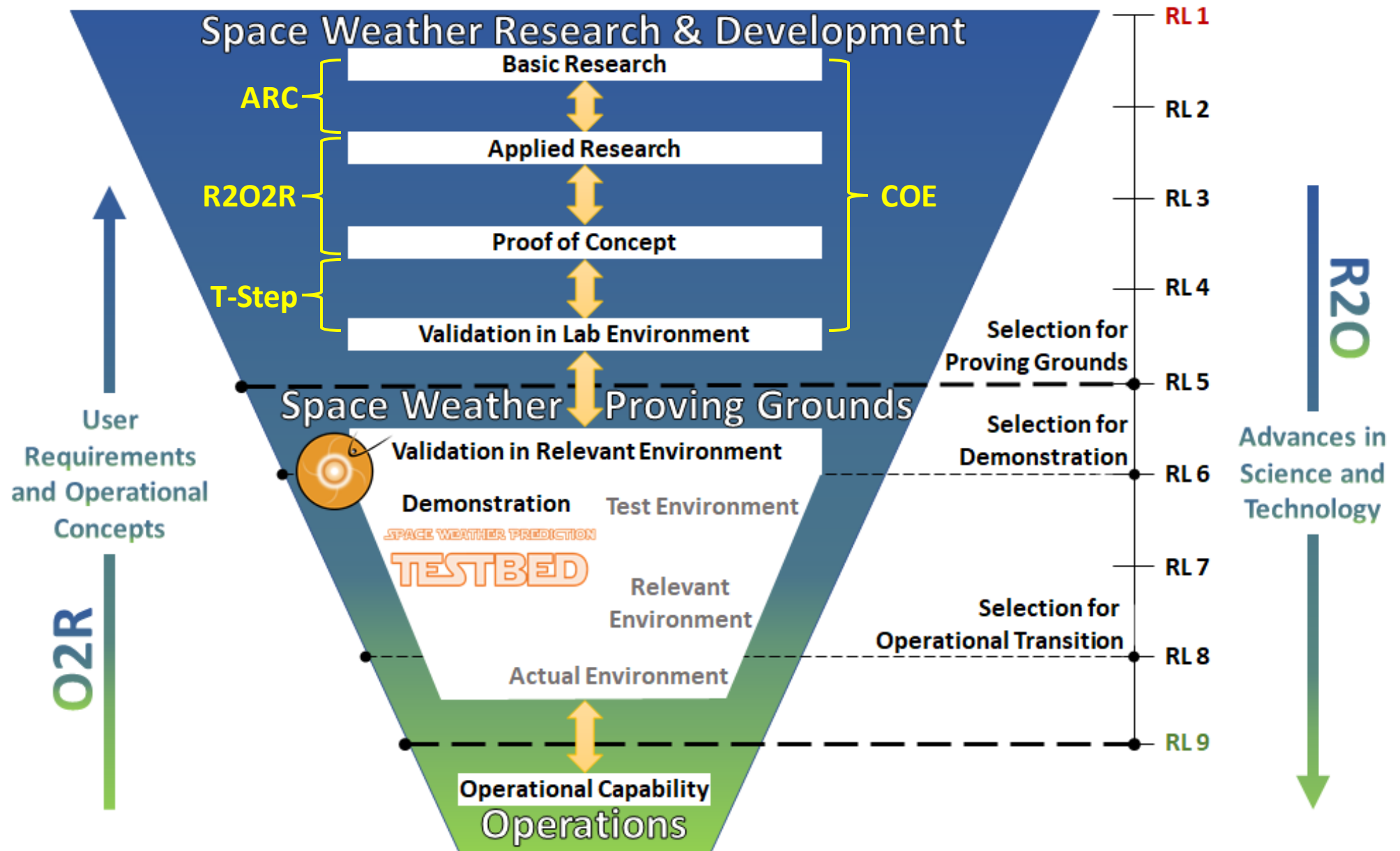
There is currently no home for supporting research needed to enable new space weather capabilities, so the R2O2R program often ends up supporting research that is less mature than is really needed if the result is going to be a transition-ready capability.

The ARC program is being developed to support early-stage/foundational research to enable better downstream results in space weather.

Space Weather Centers of Excellence (COE's)

- This is a new element in ROSES-22. There will structural similarities to DRIVE Science Centers, but this is not "DRIVE for space weather".
- The purpose of these Centers will be to provide significant long-term investment in research and infrastructure development to address major challenges in space weather in an integrated multidisciplinary fashion, explicitly and fundamentally incorporating R20 and O2R.
- Proposed Center efforts will need to be highly ambitious and should address critical challenges in space weather.
- A draft of the COE solicitation text [has been released](#) for public comment.

The R2O/O2R Process



Recent CubeSat Selections

In November 2021, HPD announced the selection of four Cubsats within the HFORT 2019 ROSES element, and a further four selections from HFORT 2020. The four listed below focus on space weather research.

Name	PI	Institute
CubIXSS: The CubeSat Imaging X-ray Solar Spectrometer	Amir Caspi	Southwest Research Institute
Sun Coronal Ejection Tracker (SunCET)	James Mason	Johns Hopkins University/Applied Physics Laboratory
DYNamics Atmosphere GLObal-Connection (DYNAGLO)	Aimee Merkel	The Regents Of The University Of Colorado
WindCube	Scott Sewell	University Corporation for Atmospheric Research

Small Business Innovation Research (SBIR)

NASA's SBIR program seeks to transform scientific discovery into products and services through innovations that have the potential for infusion into NASA programs and missions, the potential for commercialization into NASA relevant commercial markets, and that have a societal benefit.

- 2022 Phase I Solicitations Now Open, due March 9, 5:00 p.m.
 - Successful awardees can receive \$150,000 during the six-month Phase I
 - After Phase I, Phase II awards of \$1,000,000 are possible for prototype development over two years; other funding opportunities follow.
- Of specific interest to this group is the Space Weather Research to Operations (R2O/O2R) Technology Development subtopic, prioritizing:
 - Space-weather-forecast-enabling technologies
 - Commercial and decision-making applications for space-weather technologies
 - Space weather advanced data-driven discovery techniques
 - Space-weather instrumentation.

Recent Starlink Event

Overview of Event

- CME (Coronal Mass Ejection) on Jan 29, 2022 @ 23:36Z
- Within hours, NOAA and NASA had identified this CME, tracked it and analyzed it
- CME drove significant energy input into upper atmosphere, substantially changing the orbital drag environment
- SpaceX launched the Starlink satellites ~12 hours into the storm, after the thermosphere had undergone significant heating and expansion, raising the orbital drag environment significantly
- The satellites were not designed to operate in this environment and had limited delta-v capability to overcome the drag. Their orbits degraded and they re-entered Earth's atmosphere, resulting in a loss of 38 satellites, and projected \$12-24M in financial losses plus launch costs

Takeaways

- This was a minor storm.
 - Current frequency of storms this size: ~1/month
 - More frequent, larger storms will happen as we approach solar max (est. 2025)
- Had there been real-time data from a mission like GDC available, the spacecraft operator would have seen 50% density increase outside their past performance history envelope and presumably delayed the launch.

