SmallSat Access to Space

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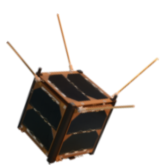
About Me

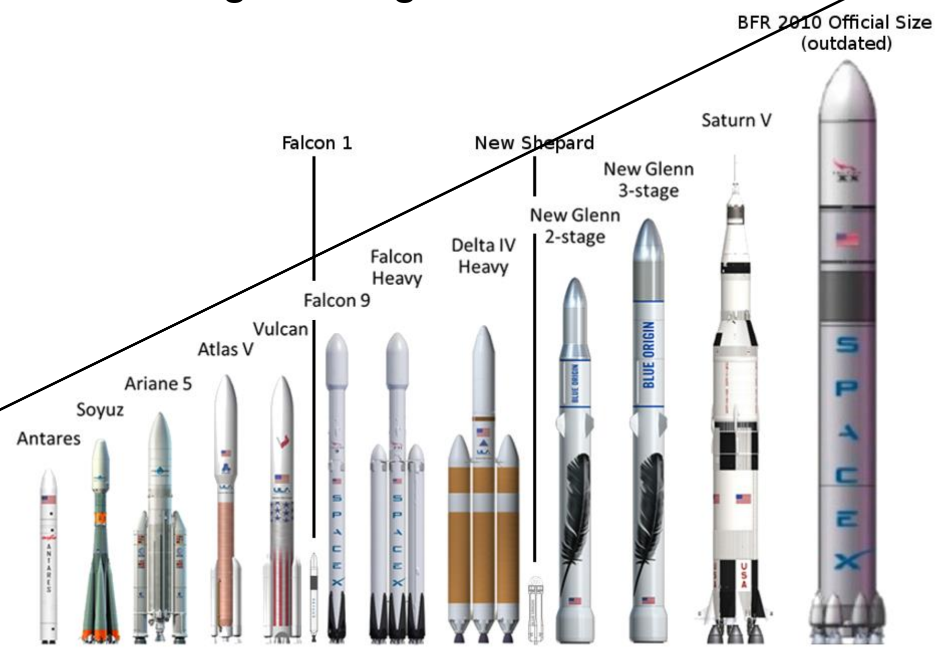
- Systems Engineer, NASA/JPL
  - Systems Engineering Division, Mission Concept Systems Development (312A)
- West Virginia University 2009-2015
  - College of Engineering & Mineral Resources
  - Department of Mechanical & Aerospace Engineering
  - Advanced astrodynamics, fluid mechanics, modern/astro-physics
- Relevant Experience
  - SunRISE SMEX proposal SE
  - VAMOS PSDS3 LSE
  - NASA/JPL Team X/Xc systems engineer
  - Discovery, New Frontiers proposals

Problem Statement

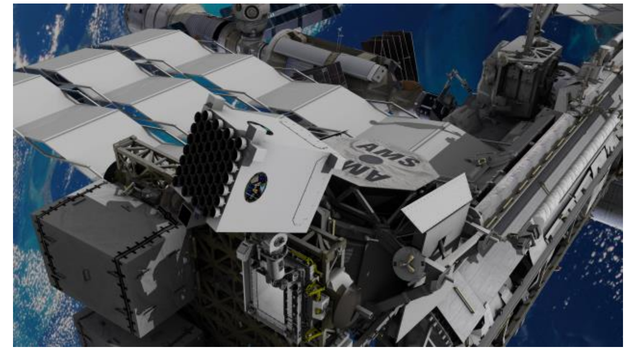
- Launch is expensive, but necessary, so NASA sometimes buys your ride
  - But buying your own ride can broaden your option space
- Small spacecraft <u>can</u> perform significant science
  - Simple payloads or complementary instrumentation (SoO)
  - Multiple destinations, distributed measurements in time and space
- Small spacecraft <u>can</u> perform lean science/engineering
  - Technology demonstration
  - TRL maturation
  - High-risk and/or low-cost feats
- High-risk, low-mass, low-budget…
  - Don't need, <u>can't</u> afford an EELV
  - LVs don't scale quite this small!



Linear extrapolation!
…right?



Launch Options for Small Missions

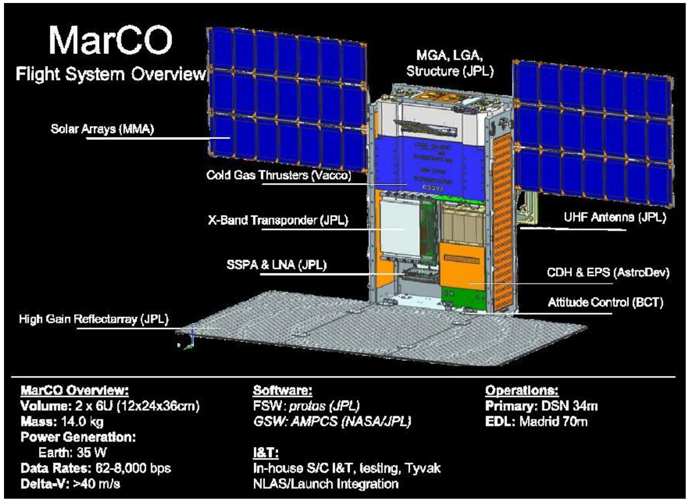


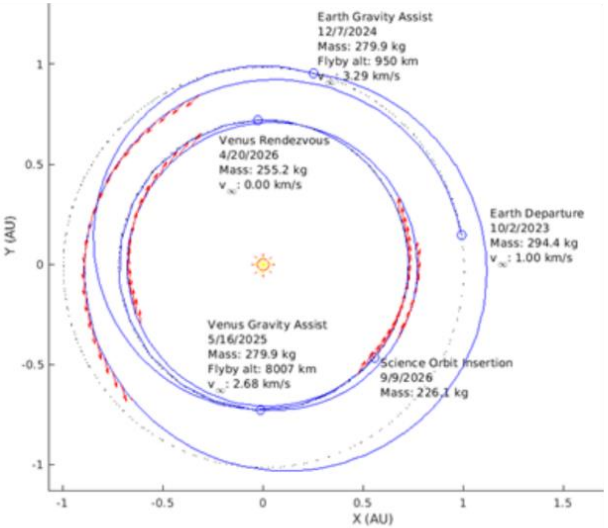
NICER on the ISS, NASA Goddard Space Flight Center

- Small dedicated (classical) launchers
  - More freedom, less possibilities (mostly LEO)
  - Electron
  - Pegasus/XL
  - Sounding rockets (suborbital)
- Rideshare Brokers
  - Can reach “better” orbits for science, but have to contend with more regulation and risk mitigation, sometimes at the mercy of the primary payload
  - ISS Commercial Re-Supply (CRS), Dragon, Cygnus
  - Planetary rideshare, ESPA/Grande
  - GEO communications satellites (PODS)
- Hosted payloads
  - Cheap access to host power, communications, thermal, but subject to restricted destination or pointing; flying in the margins of the host, easily de-scoped
  - ISS-hosted instrumentation (NICER)
  - GEO communications satellites (GOES Solar X-ray Imager)

SmallSat Propulsion- The Effects

- Typically, course-changing propulsion reserved for the most sporty of SmallSat/CubeSats
  - Propulsion limited to RCS/RWA desaturations or minor course corrections
  - Example: Mars Cube One (MarCO) direct injection to Mars w/InSight
- SmallSat (ESPA/Grande) SEP is budding, and is enabling for mass/volume limited spacecraft with a wealth of time and/or solar power
  - Example: VAMOS mission concept GTO to Venus

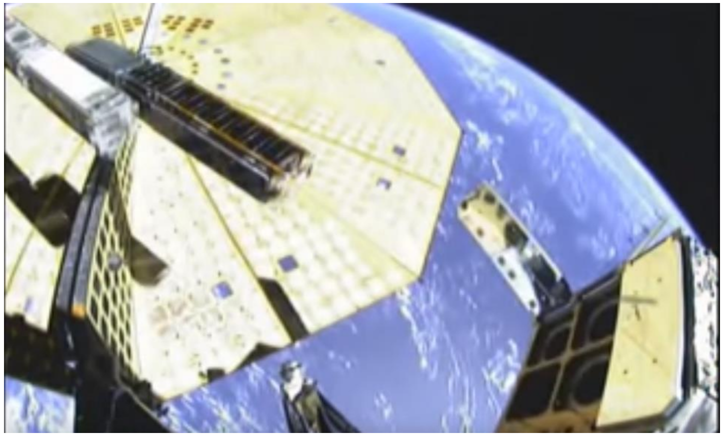




- https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/marco
- Didion, Komjathy, Sutin, Nakazono, Karp, Wallace, Lantoine, Krishnamoorthy, Rud, Cutts, Lognonne, Drilleau, Makela, Grawe, Helbert, "Remote Sensing of Venusian Seismic Activity with a Small Spacecraft, the VAMOS Mission Concept", IEEE Aerospace Conference, 2018

SmallSat Deployment Concerns

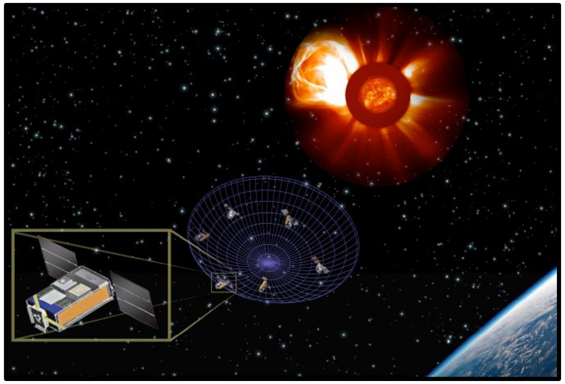
- SmallSat rideshares flying in the margins of larger primary payloads
  - Deployment time, location, velocity, direction often restricted by the interests of the $B primary
  - Host risk posture dictates all these things, as well as “dwell” period before SmallSat can power on and begin operations
  - Deployment conditions can be negotiated, but can be out of the control of the hosted SmallSat(s), and may not be known until late phases in development
  - Example: RainCube/Tempest-D will be deployed from the ISS, but the precise start of their missions is uncertain and depends on ISS operations

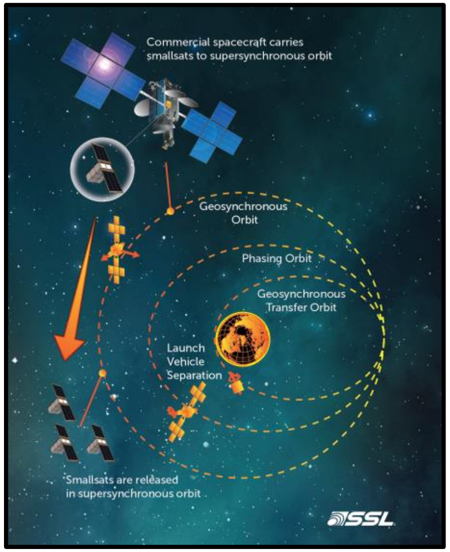


- “ISARA SmallSat Deployment”, https://www.youtube.com/watch?v=7uGye244hhg, Orbital ATK & NASA

Case Study: SunRISE SMEX MoO

- Six 6U CubeSats form a synthetic radio aperture to observe solar radio emissions, coronal mass ejections
  - Agnostic to most orbital parameters, but require isolation from Earth's ionosphere
  - ~100 kg total, each need propulsion
  - SSL PODS program delivery to super-GEO
  - Deployed by rotating the host over hours

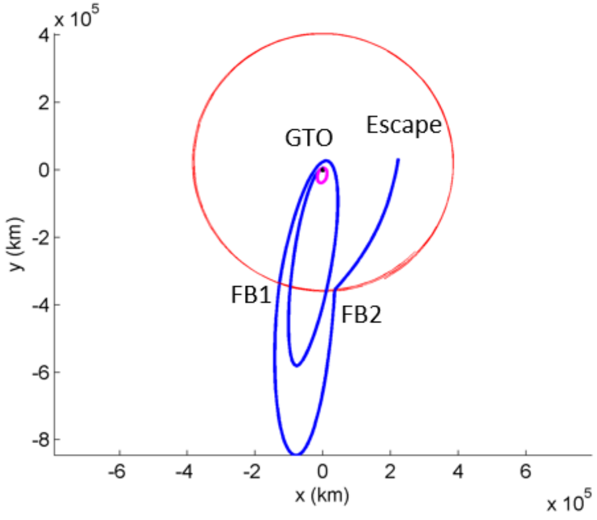


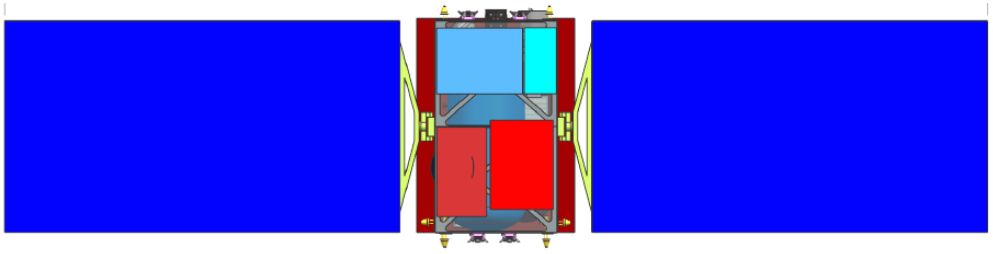


- Alibay, Lazio, Kasper, Neilsen, "Sun Radio Interferometer Space Experiment (SunRISE) Proposal: Status Update", 31st Annual AIAA/USU Conference on Small Satellites, 2017
- Alibay, Kasper, Lazio, Neilsen, "Sun Radio Interferometer Space Experiment (SunRISE): Tracking Particle Acceleration and Transport in the Inner Heliosphere", IEEE Aerospace Conference, 2017
- Stuart, Dorsey, Alibay, Filipe, "Formation and Position Determination for a Space-Based Interferometer in GEO Graveyard Orbit", IEEE Aerospace Conference, 2017
- https://www.sslmda.com/html/pressreleases/2017-12-11-SSL_to_provide_access_to_space_for_small_satellite_constellation.php

Case Study: VAMOS PSDS3

- Planetary SmallSat concept, ~ESPA/Grande class to Venus
  - No funds for dedicated launch
  - No immediate prospect for a Venus-bound rideshare
  - Utilize the popular GEO/GTO market, escape under own power, SEP cruise





*Concept Drawing

- Didion, Komjathy, Sutin, Nakazono, Karp, Wallace, Lantoine, Krishnamoorthy, Rud, Cutts, Lognonne, Drilleau, Makela, Grawe, Helbert, “Remote Sensing of Venusian Seismic Activity with a Small Spacecraft, the VAMOS Mission Concept”, IEEE Aerospace Conference, 2018
- Sutin, Cutts, Didion, Drilleau, Grawe, Helbert, Karp, Kenda, Komjathy, Krishnamoorthy, Lantoine, Lognonne, Makela, Nakazono, Rud, Wallace, SPIE Astronomical Telescopes + Instrumentation, 2018

Conclusions

- Launch services don’t necessarily scale down to SmallSat class in an intuitive manner, so SmallSat launch must be approached as an entirely new school of launch services.
- SmallSat propulsion technology also has scaling issues, and concepts should not count on the ability to make large maneuvers (e.g. launch to LEO but transfer to SSO).
- Creative use of propulsion w/common or affordable rideshare opportunities can be mission-enabling, but will prove to be more driving than with large, classical spacecraft.
- SmallSat mission concepts must be extraordinarily flexible to variable launch and deployment conditions, and are at the mercy of what the high-rolling missions are doing and the amount of risk they are willing to accept.

Contact & Acronyms

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Acronyms

- CRS- Commercial Re-Supply
- EELV- Evolved Expendable Launch Vehicle
- ESPA- EELV Secondary Payload Adapter
- GEO- Geostationary Earth Orbit
- GOES- Geostationary Operational Environment Satellite
- GTO- Geosynchronous Transfer Orbit
- ISARA- Integrated Solar Array and Reflectarray Antenna
- ISS- International Space Station
- LEO- Low Earth Orbit
- MarCO- Mars Cube One
- NICER- Neutron star Interior Composition Explorer
- PODS- Payload Orbital Delivery System
- PSDS3- Planetary Science Deep Space SmallSat
- RCS- Reaction Control System
- RWA- Reaction Wheel Assembly
- SEP- Solar Electric Propulsion
- SoO- Signals of Opportunity
- SSL- Space Systems Lorale
- SSO- Sun-Synchronous Orbit

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