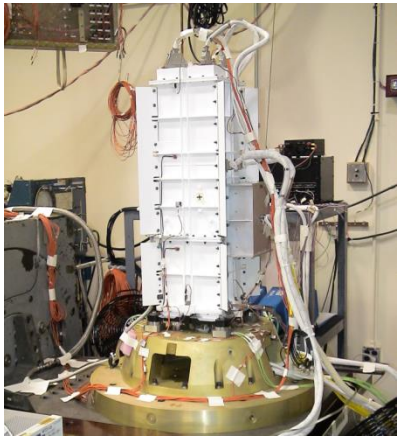
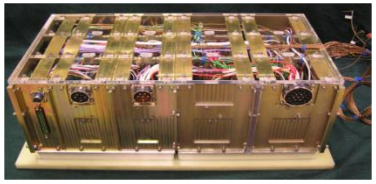
Technology Status and Roadmap Update Plan






Small Bodies Assessment Group

January 6-7, 2015

Arizona State University, Tempe, Arizona

Information presented for discussion purposes only.

Previous Roadmap Effort

- The first SBAG technology Roadmap was presented January, 2011
- The basis/input was also included in Decadal Survey / strong agreement
- The last update occurred in summer of 2012
- Completed with significant input from both the technology and science community
  - Almost entirely mission driven

- SBAG Roadmap presented to a wide range of audiences
  - SBAG, IPEWG, IEEE, JPC, etc.

- Several technologies have evolved, needs have evolved, and the model for technology investment advocacy has evolved
  - A Space Technology mission directorate has been formed
  - Investments are made primarily by technology area PI recommendations
  - Focus on capability driven
  - Technologies often need to be "Game Changing"
  - Technologies are often "widgets" over systems and needed operational support tools
    - Counter to Decadal Survey Recommendations

Previous roadmap effort completed, but much has changed.

Original Charter

SBAG will Identify the technology drivers and common needs for likely future missions.

SBAG will provide a recommendation for balance between near-term technology and those for the following decade.

SBAG will provide a recommendation for balance between technologies targeting competed missions and the Cryogenic Sample Return.

SBAG will provide a recommendation for prioritization of subsystem technologies.

SBAG will provide a recommended de-scope plan analogous to decadal survey.

Recommendations are limited to spacecraft systems and subsystems, instrument capabilities and sample collection, verification, encapsulation, and return technologies.

- No specific science instrument advocacy
- No facilities, curation processes, or simulant development

The goal was to augment the decadal survey recommendations.

Charter was science focused, SBAG is also chartered by HEOMD and now includes Planetary Defense.

Recommendations Reminder

What was in the last roadmap?

- Power Systems – Restart Pu production, Improved solar power alpha (e.g. ST-8 array capability), ASRG
- Propulsion Systems – Complete NEXT, provide an affordable EP option for Discovery
- Remote Sensing Instruments – High resolution topographer, low speed dust analyzer, advanced imager
- In-Situ Instruments – Seismic, material dating, compositional analysis
- Sample Return Technologies
- Communication Systems – Optical communications
- Ground Based Asset Technologies
- Support Tools and Capability
  - Simulants, Lab. Facilities, trajectory design, etc.
- Extreme Environments

Recommended two categories of investments:
1) High ROI / High infusion opportunity near-term investments
2) Technologies to enable sample return or cryogenic sample return the following decade

Relevant Technology Progress - RPS

RPS's are a critical resource to execute most missions from the National Research Council's National Academy of Science Decadal Survey of Planetary Science for the period 2013-2022.

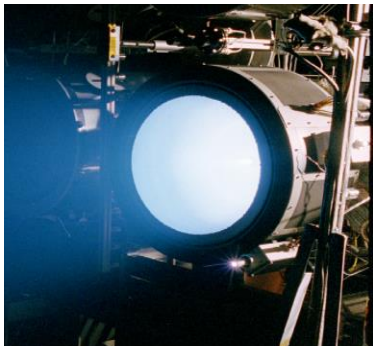
Previous Roadmap Recommendation: Restart fuel production, mature the ASRG

- Funding responsibility for sustainment of RPS operations transferred from DOE to NASA in FY14
  - DOE infrastructure for maintaining worker certifications, operational maintenance, heat source manufacturing, etc. to support future RPS fueling and assembly
- NASA continues to fund the Plutonium-238 Supply Project to redevelop production capability
  - Goal of 1.5kg/yr of Plutonium Oxide production capacity by ~2021
  - Pu-238 production demonstration with quality testing planned to start in 2015
- Current Plutonium-238 inventory is sufficient to fuel NASA missions planned for the next decade: Mars 2020 (1), Europa (4) and (2) more MMRTGs.
- ASRG flight development cancelled due to budget limitations
  - ASRG components at the termination of the flight project have been assembled into an "engineering unit" and are undergoing tests at NASA GRC using electric heat sources
- Continuing plans for next generation power systems
  - Thermoelectric technology to improve MMRTG capability
  - Currently engaged with DOE in Technology Readiness Assessment of the ASRG hardware to inform development path

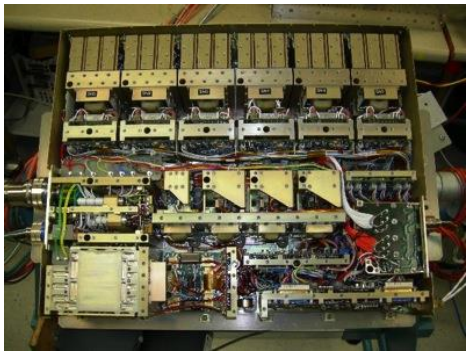
The RPS program has undergone major changes since the last SBAG roadmap, with more funding required for DOE and NASA efforts reduced.

Relevant Technology Progress – NEXT-C

- NASA Science Mission Directorate has committed to offering two NEXT thrusters and Power Processing Units (PPUs) as Government-Furnished Equipment for the 2014 Discovery Announcement of Opportunity
  - Guidebook posted in AO Library includes technical data and NEXT-C project information
- NASA Glenn Research Center is pursuing a cost-shared procurement to develop and commercialize this hardware; RFP was posted on September 25th
  - NNC14515408R
- NASA's intent is to preserve the capabilities that apply to NASA missions while allowing industry to adapt the designs to other customer needs
- Project will advance PPU to TRL6 prior to flight hardware build
- Planning Flight Hardware Delivery of January 2019.



PM Thruster



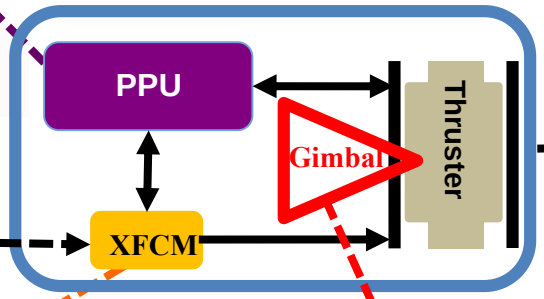
PPU Testbed

An EP Option is available for the ongoing Discovery solicitation.

Relevant Technology Progress - Hall

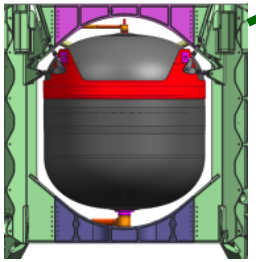
- EM PPU TRL5 Complete (include DCIU board)
- QM PPU TRL 6+ FY17/Q3 Completion

- Hall systems have advanced significantly in the past few years and offer lower cost propulsion options
  - Magnetic shielding life extension
  - PPU maturation through SBIR Program
  - Options for commercial and NASA thrusters



High Voltage Hall Accelerator is 4 kW class high T/P and high specific impulse capable thruster

- HiVHAc EDU TRL5 Complete
- HiVHAc+ TRL5 FY15/Q4 Completion
- HiVHAc+ TRL6 FY17/Q1* Completion (6,000+ hrs of qualification test with XFCM and EM PPU)



Lt Wt propellant tank

VACCO Xenon Flow Control Module (XFCM) TRL 7- Complete

Gimbal

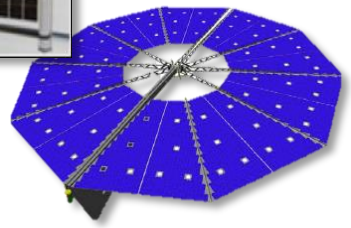
Hall options offer lower cost system potential for Discovery missions. Targeting availability end of FY17.

Relevant Technology Progress – Solar Power

- Solar Power Systems
  - Nearly all missions use solar power
  - Today's SOA is 100 – 120 W/kg
  - Dawn ~82 W/kg
  - ST-8 goal was 175 W/kg
  - Orion expected to achieve 100 W/kg
  - **Recommend to mature solar array to true TRL-6 demonstrating 175 W/kg**

- STMD initiated an Advanced Solar Array Development

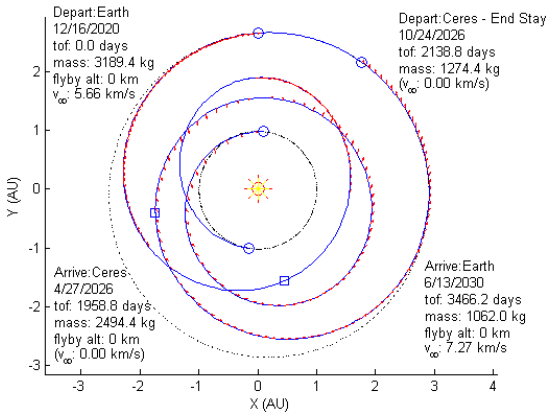
  Goals:
  - Develop reliably deployable high power solar arrays (30kW-class)
  - Operate at high voltage (160-300V) with high strength/stiffness
  - Stowed volume commensurate with mission (> 80kW/m3 for 50kW class)
  - Advanced Solar Array technologies noted, but not incentivized in the Discovery AO

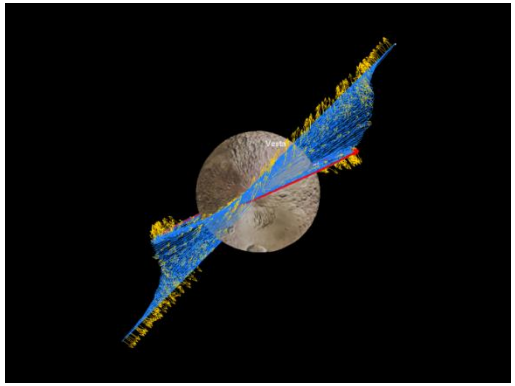


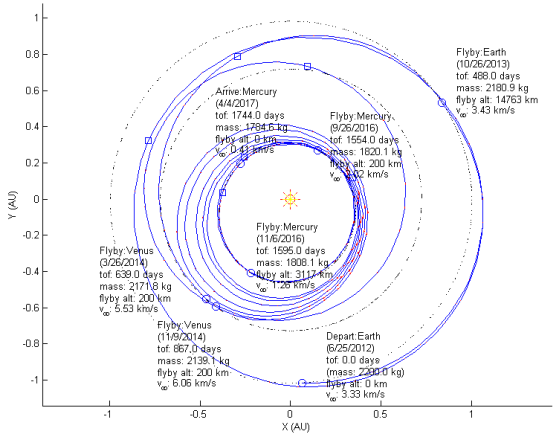
Large high power EDUs developed under STMD

Relevant Technology Progress – Mission Design Tools

- NASA has made significant progress, largely under the ISPT Program, to develop a common suit of trajectory tools available to the entire community
  - No major weaknesses associated with previous Discovery mission concept trajectory reviews
- Astrodynamics Research Grants selected developments
  - Purdue / GMAT, UC-Irvine / Mystic, UT Austin / Odyssey
  - Grants only awarded for one year; no remaining NASA Program for astrodynamics funding of these types of capabilities – Mission design is traditionally high ROI
- No longer any central Level 2 NASA program for Mission Design Tool coordination
  - SBAG has unique requirements for proximity operations with complex gravity fields
  - In-house development are increasing again







Coordination of agency mission design capabilities has degraded with the ISPT program closeout.

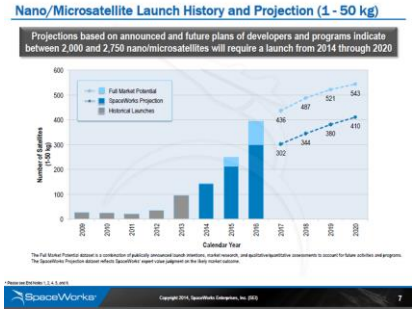
Relevant Technology Progress – Discovery

- The SBAG community must acknowledge that NASA selected three Discovery concepts for technology development, and all three are for SBAG relevant missions:
  - Whipple – Demonstration or a blind occultation technique for survey of deep space small bodies
    - Charles Alcock – SAO Cambridge
  - Primitive Material Explorer (PriME) – MAss Spectrometer for Planetary Exploration (MASPEX)
    - Anita Cochran – UT Austin
  - NEOCam – NEO Survey Detector Development
    - Amy Mainzer - JPL

While not from the "technology" funding of PSD, Discovery is investing in technology applicable for SBAG relevant instruments.

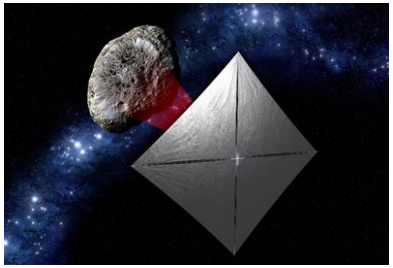
The New Area – Small Spacecraft

- As capabilities and rideshare opportunities increase, in addition to the budget pressures and acknowledgement of the breadth of targets, the desire to leverage small spacecraft to meet science and exploration objectives will increase



- A wide range of technology gaps exist for high value missions
  - Investments ongoing for propulsion, communication, power, etc.

- NEA Scout is a 6U Asteroid Reconnaissance mission
  - ~85 m^2 solar sail propulsion system
  - Manifested for launch on the Space Launch System (EM-1/2017)
  - Up to 2.5 year mission duration
  - 1 AU maximum distance from Earth



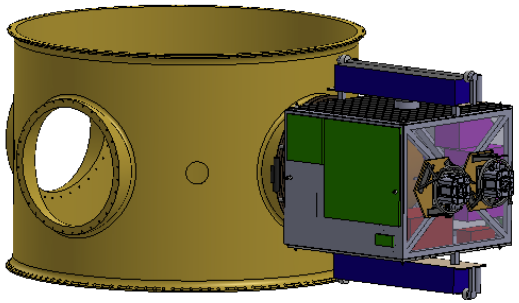
- The recent SIMPLEX solicitation is for 6U and smaller planetary science missions

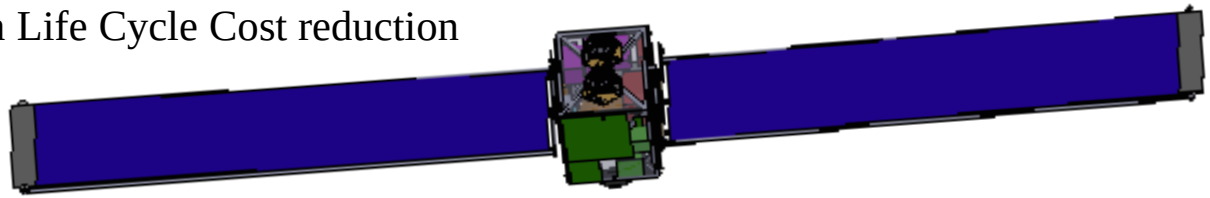
- SBAG objectives may have a unique opportunity to leverage small spacecraft
  - Technology planning must be coordinated to meet future mission objectives

Limited "mission pull" roadmap exists for small spacecraft science and exploration.

Not on a Roadmap – Iodine Propulsion

- Iodine SEP SmallSat launch to GTO can go to Asteroids, the Moon, Mars and Venus
- High density solid propellant leveraging heritage propulsion
- Funded for technology maturation to TRL 6 by end of 2016
- Launch to GTO, 24” lightband deployment
- Small Body Concept: Low-thrust Spiral from GTO to escape (~7 months) then to the NEA Bennu (~2 years) with a 3-5 month science duration for a total 3 year mission time: Total ΔV 9600 m/s. Extended mission possible.
- Communications: X-Band transponder and patch antennas for ~ 3 kbps (@2 AU distance) and tracking through 38 m ground antennas.
- Science: ~15kg payload
- Cost: ~ $130M (includes development, flight hardware, launch, operations and reserves.)
  - 3x – 5x Mission Life Cycle Cost reduction





Iodine propulsion may enable a Mission of Opportunity with every GTO launch.

Areas in Need of Awareness

- The "effective" technology procurement funds within the Planetary Science Division and HEOMD are both declining
  - One example: Increase in PSD "Technology" funds is required to cover DOE cost increases.
    - Less technology funding is available for PSD within NASA
  - STMD and PSD/HEOMD technology relationships are still relatively new
    - Occasional competing objectives or investments appear uncoordinated
      - HEOMD, SMD, STMD (TDM and SSTP) Optical communication demonstrations
        - Agency prioritization/coordination for return on investment

- The In-Space Propulsion Technology (ISPT) program has been eliminated
  - NEXT is incentivized for on-going solicitation
    - Evolutionary technologies struggle in the model of STMD
  - AMBR industry infusion opportunities looking to coordinate NASA needs
- Astrodynamics Research Grants eliminated
- Mission Design Tools moving back in-house

Strong relationships between STMD and mission directorates are critical to prioritizing science exploration and technology needs, but gaps will still exist that must be filled by PSD and HEOMD.

Technology Opportunities – Solar Power

- Solar Power Systems
  - Nearly all missions use solar power
  - Today's SOA is 100 – 120 W/kg
  - Dawn ~82 W/kg
  - ST-8 goal was 175 W/kg
  - Orion expected to achieve 100 W/kg
  - **Recommend to mature solar array to true TRL-6 demonstrating 175 W/kg**

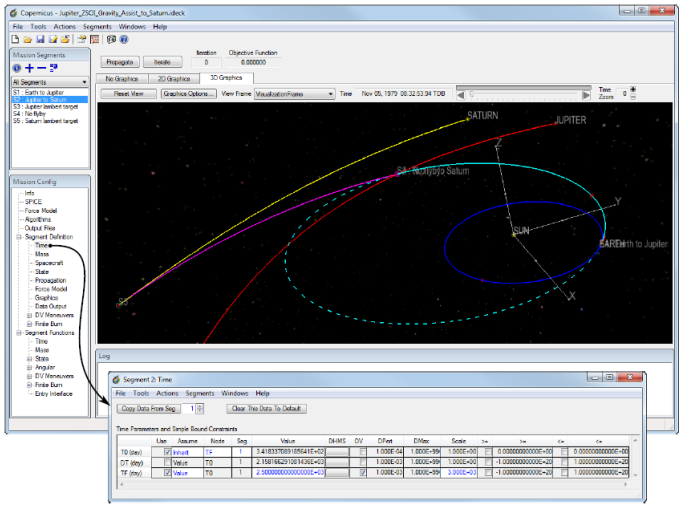
- Most relevant to SMD are moderate power level improvements
  - At the time, the contractor offered to develop and mature an SMD variant of the Ultra-flex system, meeting the ST-8 objectives for relatively low cost
  - HEOMD continues to drive their solar power system for high load capability
  - STMD is driving the technology for significantly higher power capabilities
  - **PSD specific technology needs a champion tasked to identify and coordinate technology synergy opportunities.**

With wide technology investments, synergistic opportunities need an opportunity for consideration.

Technology Opportunities – Copernicus

➢ The mission design tool, maintained in-house at JSC, is an excellent example of SBAG synergistic opportunities

- Tool originally developed under the ISPT program of PSD
- As PSD investment dropped 90%, the Constellation Program filled the gap
- HEOMD is currently the primary supporter for Copernicus
- Small tasks (<$100k) and sometimes just coordination has made large synergistic capability enhancements
- Copernicus 4.0 released late 2014 and available academic and NASA community



Synergistic opportunities have been successfully implemented previously.

Technology Opportunities – SBIRs

- Many millions of procurement funds are dedicated to SBIR investments
  - SMD instruments and technologies
  - HEOMD instruments and technologies
  - STMD technologies

- SBIR prioritization can be based on program needs, center priorities, PI interests, etc.
  - Low temperature solid propellants
  - Asteroid anchor systems
  - 6U Lunar Orbiter / asteroid explorer
  - Etc.

- Long range coordinated SBIR leverage may benefit the community

With guidance, the SBIR program may offer opportunities for SBAG relevant technology maturation.

Update Approach – Directorate Specific Needs

One of the biggest challenges for technology development is always balancing the prioritization such that the technologies are available for the missions when they are needed.

- Planetary Science and Exploration have unique technology requirements
- Small Bodies have a specific subset of technologies within the directorates
    - Discovery mission technology needs are difficult to generalize and prioritize
    - The technology near-term needs, may not align with STMD near-term objectives

The "voice" of PSD and the AGs is critical to help guide STMD investments

- Significant leverage of data from Team-X, COMPASS, MDC, Ace, etc.
- DRMs often not included in the existing STMD investment portfolio analysis
    - This is improving

Direct involvement of the STMD PIs, SMD and HEOMD is critical to the success of the activity.

Coordination between mission directorates is critical to the value of the roadmap.

Proposed New Charter

- SBAG roadmap will include high-priority technology needs that support any/all SBAG goals.
  - Science, Exploration and Planetary Defense
- SBAG will identify ongoing relevant technology investments occurring within NASA.
- SBAG will identify baseline capabilities.
- SBAG will Identify the technology drivers and common needs for likely future missions.
- SBAG will provide a recommendation for balance between near-term technology and those for the following decade.
- SBAG will provide a recommendation for balance between technologies targeting competed missions and the Cryogenic Sample Return.
- SBAG will provide a recommendation for prioritization of subsystem technologies.
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Recommendations are limited to spacecraft systems and subsystems, instrument capabilities and sample collection, verification, encapsulation, and return technologies.

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The product will be a living document to inform coordination of STMD, HEOMD and PSD/SMD investments of SBAG relevant technology needs.

Proposed Scope

- High-priority technology needs that support any/all SBAG goals
- Requested to limit document to 20 pages total
- Include “mission pull” recommendations based on preliminary science objectives and exploration strategic knowledge gaps
- Include general bus technologies for traditional Discovery and New Frontiers missions, sample return technologies and small spacecraft technologies
- Include SOA capabilities
  - Include identification of technology gaps from SOA
  - Include identification of specific SBAG gaps from ongoing NASA investment objectives
- Avoid identifying a solution by only one institute over another
- Avoid any specific instrument development
- The development plans / schedules unless specifically requested on a per technology basis and is otherwise out of scope.

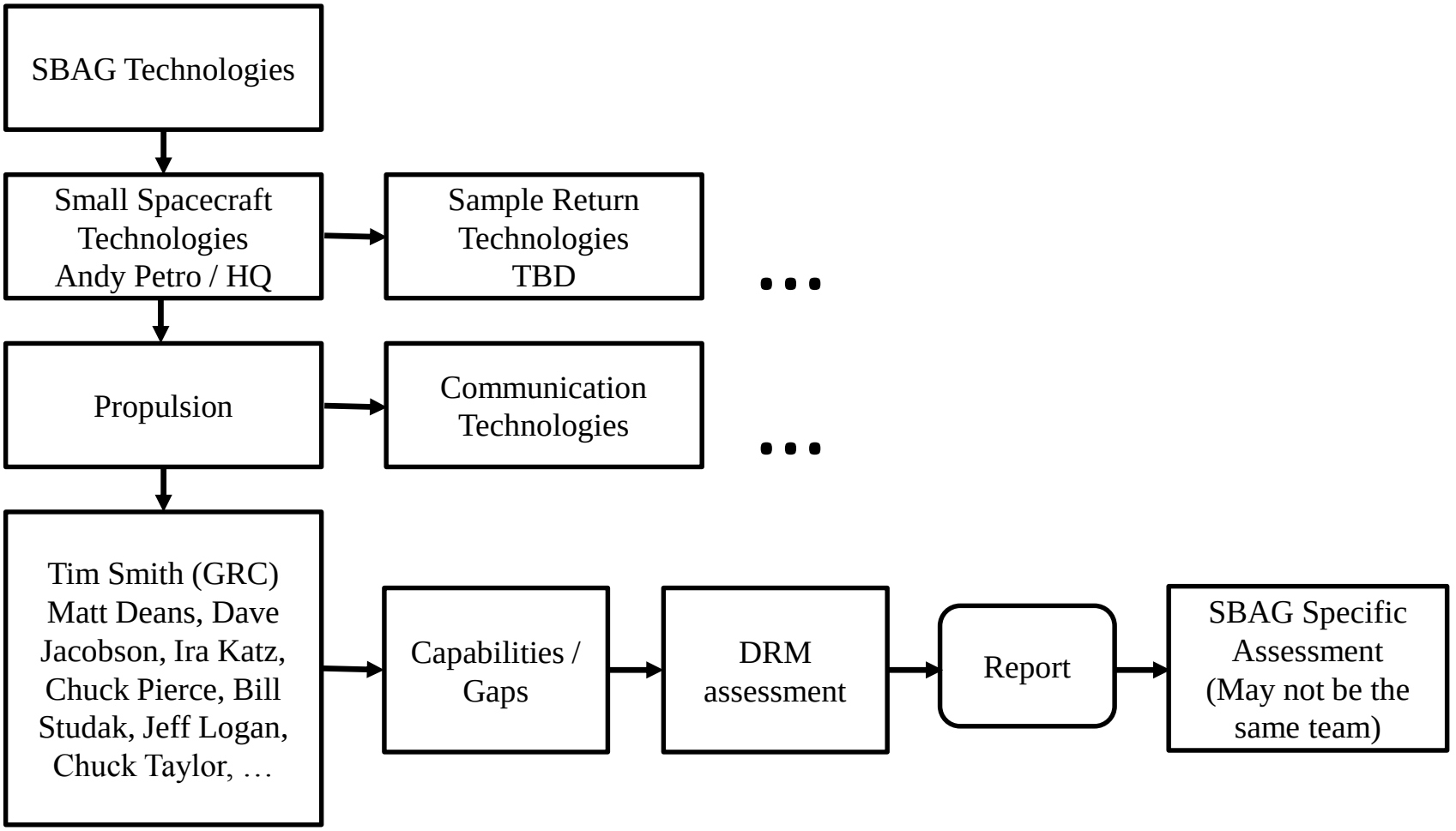
The product will be a living document to inform coordination of STMD, HEOMD and PSD/SMD investments of SBAG relevant technology needs.

Update Approach / Schedule

- Present Technology Status / Subset of Progress Since Last Roadmap – January 7, 2015
- Propose Charter / Scope and ask for community participation – January – February
- Establish community teams for categories of technologies - January – February
  - Standard Bus Technologies
  - Sample Return Technologies
  - Small Spacecraft Technology – STMD / Andy Petro, NASA HQ to lead coordination
  - Instrument Technologies
- Establish SOA Capabilities (February – June) – Present at SBAG 13 – June 30, 2015
  - Survey STMD, HEOMD, SMD programs, NASA investments and SBIR leads
  - Draft Science Objectives to be presented at SBAG 13
- Tie to mission needs and existing programs (July – November)
  - Identify gaps between technology needs to meet science objectives
  - Identify gaps between SBAG needs and ongoing capability push efforts
- Provide a draft technology roadmap for community feedback – December, 2015
- Present draft technology roadmap for community feedback – January, 2016
- Provide a new baseline of the roadmap to the community – March, 2016

The approach is to develop a community based and mission need driven technology roadmap by Spring of 2016.

Example Area – Small Spacecraft / Propulsion



Technology discipline experts for wide range of working groups.

Summary

- SBAG completed an original technology roadmap to support small body science and exploration objectives
  - Significant progress has been made for some high priority technology needs
  - Several areas could benefit from additional coordinated investments with high ROI
  - Limited progress on sample return technologies required to enable CNSR the following decade
- The objective to increase small spacecraft capabilities to enable progress towards small body science and exploration goals requires a wide range of technologies previously neglected
- The SBAG Technology Roadmap will be updated over the next 15 months
  - Update will be coordinated across SMD, HEOMD and STMD
- Community support and inputs are greatly appreciated

If you are interested in supporting the SBAG technology roadmap activity, please contact:
john.dankanich@nasa.gov