Sustained Land Imaging Architecture Study Briefing To 2014 HyspIRI Product Symposium

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Land Imaging AST Charge, Process, & Membership

Land Imaging AST Charge (September 2013)

- Define a Sustainable Land Imaging (SLI) system delivering global land-imaging multispectral and thermal infrared information for a 20-year period starting in 2018
- Provide options which consider various weightings of near-term capability, continuity/gap risk mitigation, technology infusion over the system's lifetime, and cost
- Consider refined capabilities requested by the user communities
- Include consideration of new measurement approaches, as well as potential international and private sector partnerships

AST Study Process

- Establish study trade space via expert knowledge, intensive AST discussions, and RFI responses
- Trade space is explored via several design cycles, and adjusted through each
- Appealing architectures that are likely to satisfy budget constraints are further refined and assessed

AST Membership

- Representatives from NASA/GSFC, NASA/LaRC, NASA/ARC, JPL, USGS, JHU/APL, Aerospace, and MIT/LL

Three Basic Study Tenets for the Program

- Sustainability
  - The LI program should provide the *data products* for the long haul, without extraordinary infusions of funds, within the budget guidance provided.
- Continuity
  - The LI program should continue the long term Landsat data record. This does not necessarily mean the imagery per se, but the *usable products* that define the utility of the data record.
- Reliability
  - The LI program should be robust and *not susceptible to single point failures*. The loss of a single satellite or instrument on orbit should not cripple the program or significantly impact users.

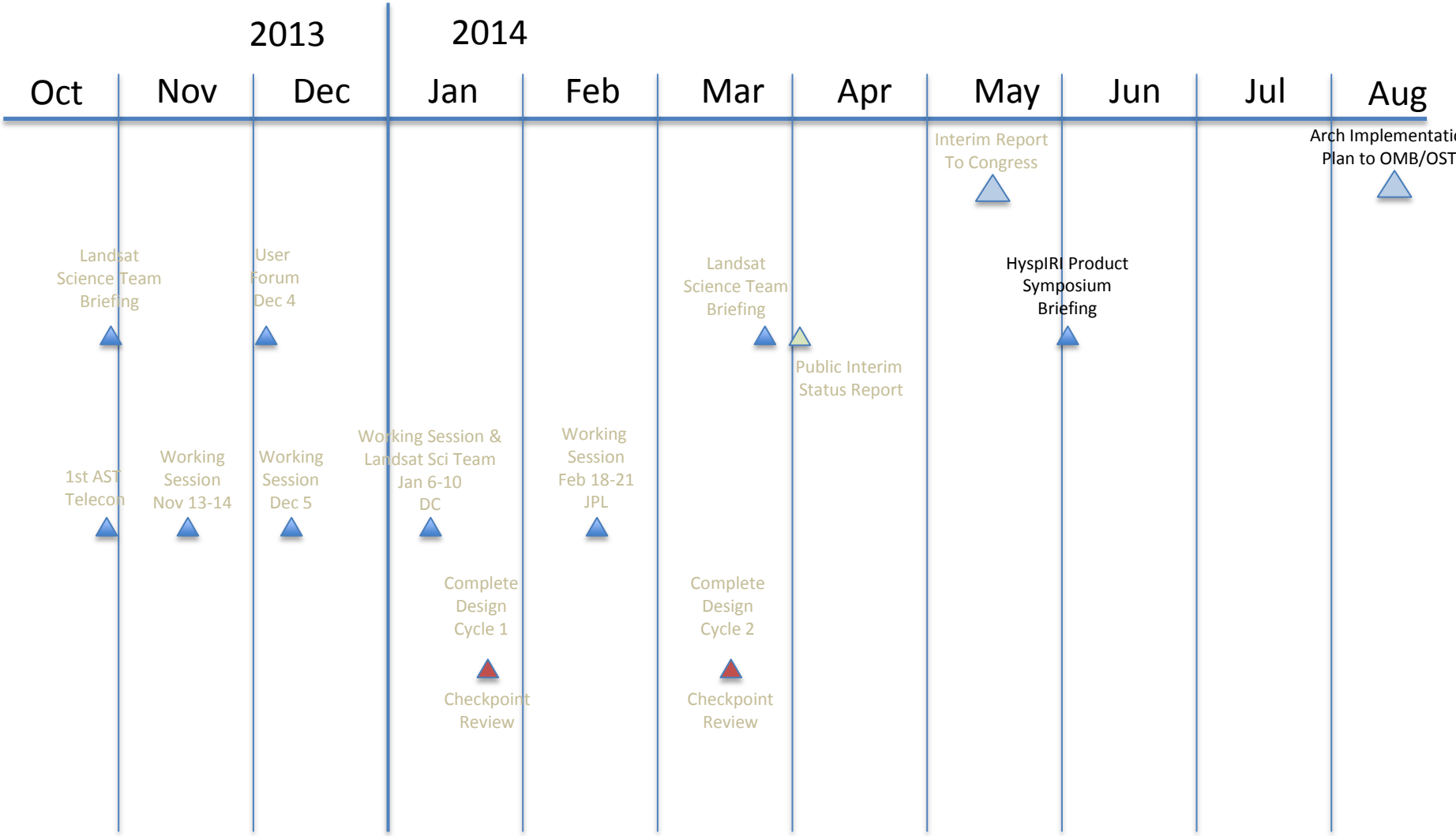
NASA Land Imaging Budget

- The President's FY 2014 Budget Submittal for NASA's Sustained Land Imaging activities, released in April 2013

$K	**FY 14**	**FY 15**	**FY 16**	**FY 17**	**FY 18**	**FY 19**
Land Imaging	30,000	84,000	94,800	117,900	117,900	-

- Per ESD direction assume for planning purposes: $120M in FY19 as the base year and inflation adjust in FY20 and beyond

AST Study Timeline & Milestones



Architecture Assessment Process Overview

- AST has attempted to map the prime study tenets of Sustainability, Continuity, and Reliability into our metrics and assessment process
- Satisfaction of user community needs is reflected by comparison to historical Landsat capabilities
  - Secondary metrics are being assessed to address the degree to which architectures satisfy other user desires
- AST process has evolved into a phased sequence to enable first phase assessment of many architectures followed by more detailed assessment of down-selected subsets
- Technical flight system concepts are first mapped to select business models to establish mission cost building blocks
- Missions are implemented as frequently as possible, constrained by the program budget profile
- Architecture performance as measured by availability and other metrics are then assessed

Assessment of Enhancements

- AST charged to also consider refined capabilities requested by the user communities and new measurement approaches
- Includes consideration of
  - More frequent revisit rates
  - More spectral bands
  - Finer spatial resolution
  - Hyperspectral
  - Other modalities (SAR/Lidar)
- Benefit and risk assessment of hyperspectral imaging being investigated by AST team consisting of JPL, GSFC, and MIT/LL in parallel to larger continuity architecture assessments
- Assessing and comparing AVIRIS to Landsat 8 imagery

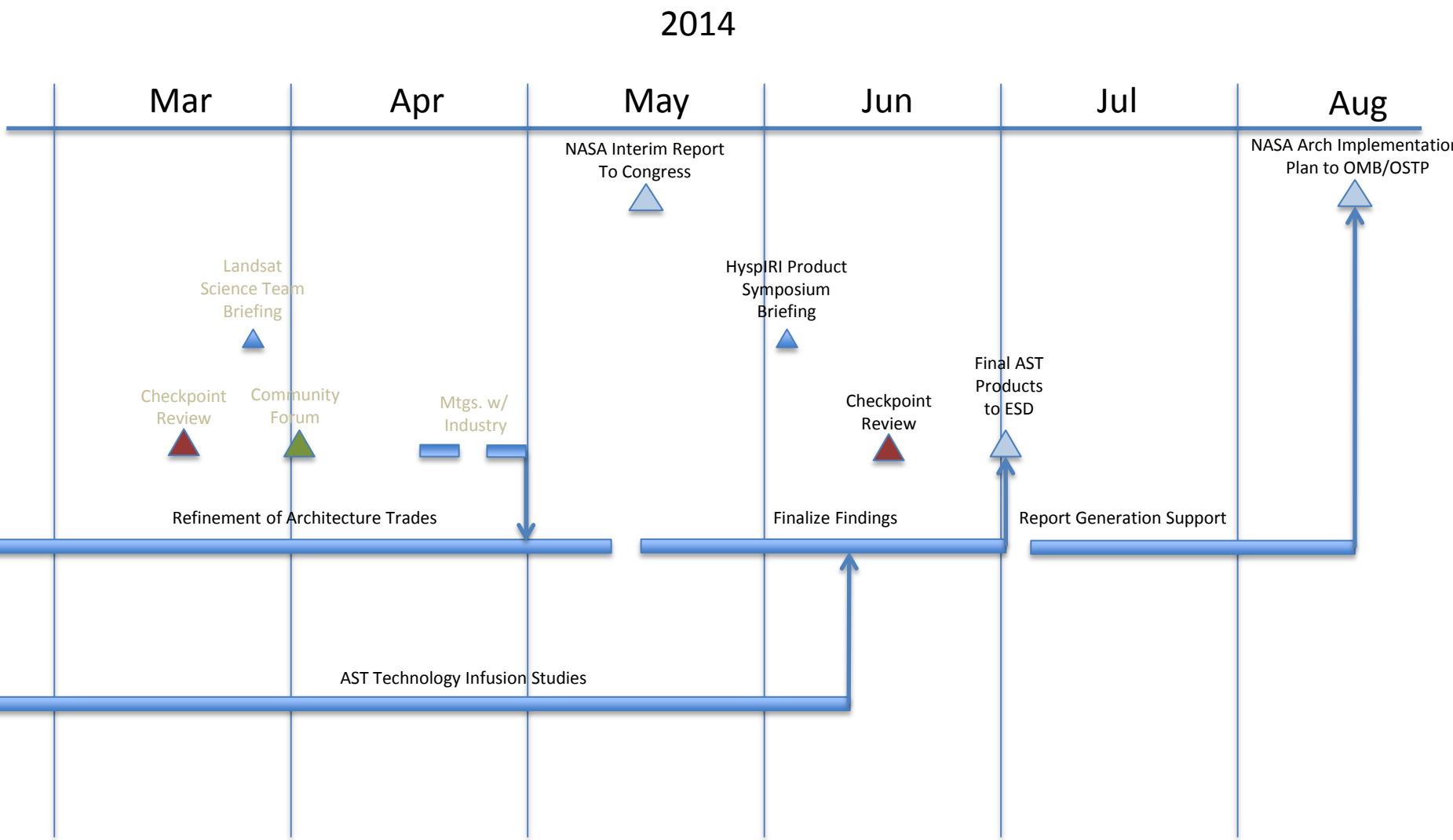
AST Observations (1 of 2)

- The future Sustainable Land Imaging program should continue to provide the *backbone* capability historically played by Landsat
  - There is currently no comparable program to Landsat: it is the reference standard for land imaging relied on by other programs
    - Sentinel 2 may become similarly capable in reflective bands, but is yet unproven
  - Landsat sets the standard for data usability; this should continue
  - Data should be ~co-temporal, coregistered, calibrated & full-spectrum: VIS-NIR-SWIR-TIR
  - Data should have routine global & synoptic coverage
  - Data needs to be acquired from a sun-synchronous vantage point
  - Land Imaging should strive to only employ mature technologies operationally
    - Demonstration of promising new technology should be done “off line”
  - Science and operational users expect and require stability
    - New approaches should enable continuation of historical record

AST Observations (2 of 2)

- BOL performance of Landsat 8 is excellent
  - Some aspects of OLI performance (e.g. SNR) may exceed the needs of many users
  - Landsat-8 (including TIRS) is likely to continue well beyond its design life
    - Possibility of random failure increases slowly but monotonically
- For a significant portion of Landsat history the repeat time has been 8 days, hence this most closely represents “continuity” to the user community
- A launch failure may occur, a random failure on orbit may occur
  - The system must be robust to a single failure
- The SLI program budget profile is the dominant driver of the architecture trade space
- AST has identified viable architectures within the constraints of the study
  - However, those approaches that satisfy the value metrics have their own unique drawbacks and risks
- AST results will inform initial SLI Program direction
  - Determine feasibility of sufficiently satisfying user needs within sustainable program
  - Identify promising architectures
  - Enable near-term decisions for initial program direction and investments
  - Ongoing studies and technology investments by the SLI program will be required to refine the program plan

AST Study Timeline & Milestones



AST Perspectives on Hyperspectral Data

HyspIRI Symposium, June 4 2014

Factors to Consider

- SLI Science and User Needs
  - Which SLI applications *require* hyperspectral data
  - Which would *benefit* from hyperspectral data?
  - Ability to use hyperspectral data to provide Landsat data products
- Technology Readiness
  - Can a spectrometer meet core Landsat-8 requirements with low risk in the near-term?
- Ground System Impacts

How Are User Needs Assessed?

- USGS National Land Imaging Requirements (NLIR)
  - elicited 151 distinct, representative user applications where Landsat data is used routinely to provide consistent services or informational products
- Landsat Science Team Input
  - Definition of Landsat Continuity (white paper)
  - Parametric studies on data quality
  - Role of Sentinel-2 in SLI Program (white paper)
  - Role of Hyperspectral data in SLI (email query)
- NRC Report “Landsat and Beyond”
- NASA Science needs

AST Findings: User Needs

- The SLI Program should be designed to support the broad range of national and global land monitoring capabilities, and provide continuity with the historic Landsat archive

- The current Landsat user community places the highest priority on increasing revisit frequency
  - Improved ability to defeat cloud cover and use “every clear pixel”
    - Critical for mapping of land cover and vegetation change in cloudy areas, including tropics
  - Intra-annual spectral changes (e.g. phenology) seen as key for mapping vegetation type and condition
  - More frequent revisit advances hydrological and cryospheric applications, where conditions change daily to weekly

- Hyperspectral data are critical for specific applications
  - Detailed mapping of vegetation composition (e.g. species/community level)
  - Biogeochemistry & Photosynthetic rate controls
  - In general, hyperspectral data offer a potential for physically-based modeling of ecosystem function, and ecosystem responses to disturbance, management, and climate change

Imaging Spectroscopy Technology

- Imaging spectroscopy could provide core multispectral data for SLI
  - In theory, aggregating 10 nm bands from current imaging spectrometer designs should meet OLI SNR requirements
    - A larger aperture may be required to compensate for grating efficiency losses
    - Spectrometers that only meet aggregated L8 SNR requirements may not provide adequate SNR at 10nm for useful hyperspectral applications
- AST has concerns about *near-term* ability to implement a wide FOV spectrometer that meets all Landsat-8 performance requirements
  - Stray light due to diffraction grating limitations
    - Spatial
    - Spectral out-of-band
  - Spectral band edge locations and extent for narrow SLI bands
  - Potential for increased polarization sensitivities with a grating
- These risks are not seen as permanent – mitigation options include:
  - Additional design & testing using laboratory and airborne systems
  - Tech demo missions, perhaps in cooperation with SLI
  - HyspIRI mission implementation

Preliminary Conclusions

- AST is not recommending *requiring* hyperspectral data for a near-term ("Landsat-9") mission
  - Using a spectrometer to obtain L8-type multispectral data remains a possibility under some near-term options
- AST is considering options for integrating imaging spectroscopy into future SLI missions
  - Although hyperspectral data are not seen as an immediate requirement, user experience with upcoming missions (e.g. ENMAP, HyspIRI) may accelerate demand for these data
  - Spectrometers may prove to be the most cost-effective approach for multispectral observations
  - Tech demo (ESPA-class) missions are an attractive option
    - AST is an advocate for laboratory and space demonstration of a compliant, perhaps narrower FOV hyperspectral capability
    - Space demonstration would enable data assessment by broad user community
    - Small spectrometer could provide geographic sampling (rather than global coverage) with 30 meter resolution, while demonstrating consistent radiometry across FOV
    - Could provide substantial science benefits while demonstrating ability to meet Landsat-8 data quality requirements
  - Possible long-term migration to primary hyperspectral capability for SLI

Feedback Desired

The AST is interested in feedback from the hyperspectral science community, including the HyspIRI science team:

- General feedback on this presentation and the SLI program in general:
  - Views on the role of hyperspectral data within the context of SLI and Landsat Continuity
  - Views on the technical challenges presented here
- Thoughts on how best to demonstrate hyperspectral capabilities to mitigate SLI risk
  - Is there interest in a small, secondary hyperspectral payload in the “Landsat-9” or “Landsat-10” era?
  - Early demonstration of wide-FOV, 30m spectroscopy
  - Science utility of a systematic global sample?
  - AST is recommending small secondary payloads to demonstrate technology
    - Would likely require funds external to SLI budget