Section 9

ALI Lessons Learned

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Topics of Discussion

- Programmatic Issues
- Technical Issues
- Summary
Programmatic Issues
Issue: The Grating Imaging Spectrometer (GIS) was added to ALI, three months after program start.

- The GIS integration complexity and cost and schedule impact were underestimated and ultimately led to the elimination of both the GIS and the Wedge Imaging Spectrometer (WIS).

Lesson: Mission changes should be considered very carefully
Issue: The spacecraft structure was changed from composite to aluminum ten (10) months after program start (February 26, 1997) requiring substantial redesign of ALI structures.

- The launch vehicle was changed from the Taurus to Delta 2 (January 28, 1997) increasing mass allocations.

- The Project Office traded spacecraft mass for cost and decided to switch from composite to aluminum structure.

- The impact of the resulting ALI redesign was not fully appreciated.

Lesson: Requirements and interfaces need to be frozen early in the design process.
Programmatic (3 of 3)

- **Issue:** The decision was made to build all electronics assemblies without Engineering Development Units (EDU) or Qualification Units to “reduce cost”.
  
  - *This delayed problem discovery which made correction more difficult and more, not less, expensive.*

- **Lesson:** The EDU serves a useful purpose and should not be skipped.

- **Issue:** The mandated 10% reserve proved inadequate for a program for flight-validation of new technologies.
  
  - *The new technologies incorporated in ALI required further development to produce flight hardware.*

- **Lesson:** Adequate reserves should be provided (e.g., 30%), commensurate with technology readiness, to resolve unanticipated problems and to pursue back-up options.
Technical Issues
**Focal Plane Contamination**

- **Issue**: Contamination accumulates over time on the ALI focal plane filters. The contaminants are boiled off through periodic bake-outs on-orbit, every 10 days, lasting 20 hours.
  
  - While the focal plane is warmed up, the VNIR data are still good, however, the SWIR data are not.
  
  - Contamination is no longer present in the SWIR bands.
  
  - Almost all materials used on ALI met NASA outgassing specifications including the Z-306 black paint.
  
  - All components were baked out. Cost and schedule sometimes drove bake-out duration decisions.

- **Lesson**: Need uniformity across the board for baking out components to minimize contamination potential in vacuum testing and on orbit.
Leaky Detectors

- **Issue**: Two ALI detectors (pixels), out of a total of 15,360, are coupling their signal to the neighboring detectors creating streaks in the images.
  - The problem was not evident in the original test data (flood illumination of focal plane detectors).
  - Special algorithms have been developed that greatly reduce the effects of leakage, virtually eliminating it.

- **Lesson**: Future Sensor Chip Assemblies should be screened to eliminate any that have leaky detectors.
Vacuum Chamber Window Effects

- **Issue**: During optical calibration under thermal-vacuum, it appeared that the focus of the instrument had shifted.
  - It was determined both experimentally and analytically, that the focus shift was due to the chamber window distortion due to the temperature gradient.
  - A technique was developed to eliminate this effect.

- **Lesson**: Understand all optical effects of thermal-vacuum chamber windows and address them in the test plan and test procedures.
Other Technical Issues (1 of 4)

- **Instrument Alignment on S/C**
  - **Issue:** ALI and Hyperion were not co-aligned.
    - Each instrument’s alignment relative to the S/C was carefully measured and recorded.

- **Instrument Pointing**
  - **Issue:** It took several weeks to establish accurate instrument pointing on-orbit.
    - S/C pointing was well established.
  - **Common Lesson:** Need a System Engineer to oversee and correct critical performance issues at the system level.
Other Technical Issues (2 of 4)

- **Internal Lamps**
  - **Issue:** The brightness of the lamps changed on-orbit (increased).
    - Filaments run hotter in zero-G because of the absence of gas convection.
  - **Lesson:** Gas filled lamps are great for checking day-to-day repeatability but should not be used as a radiometric transfer standard.

- **Subsystem Early Consideration**
  - **Issue:** It is difficult to add-on subsystems (e.g., reference lamps) that are not part of the design considerations from the beginning.
  - **Lesson:** Include all subsystems in the early planning.
Other Technical Issues (3 of 4)

- **On-orbit Data Processing**
  - **Issue:** After launch, the Level 0 data formats changed several times.
    - Shifting of pixels and bands
    - Left-right reversals
  - **Lesson:** The ICD regarding Level 0 processing and the Calibration Pipeline should be completed and frozen before launch.

- **Schedule**
  - **Issue:** The ALI schedule remained very tight even when it became clear that other parts of the program were slipping.
    - Opportunities to avoid overtime and do a more thorough job were missed.
  - **Lesson:** Harmonizing all delivery schedules can produce some program benefits.
More Lessons Learned

- Insist on thorough documentation of all vendor (subcontractor) tests.

- Document the “as-built” characteristics of each part.

- Provide a complete photo documentation of the instrument prior to delivery, with close-ups of all critical items.

- Comparison of several independent calibration techniques has proved to be extremely valuable both in ground and on-orbit measurements.

- Calibration of each detector of a large focal plane is a manageable job but requires thorough preparation of test plans, test instrumentation and associated software to process the large volume of data.
Summary

- Many of the lessons learned have a common thread: the tight development schedule and budget require greatly focused mission objectives.

- A highly motivated, dedicated team can overcome the inevitable problems associated with a high-risk technology validation mission and bring about success.