Maintaining Ground Software and Hardware Over Missions That Span Multiple Decades

Lessons from the New Horizons Mission

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Agenda

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- The Challenge – Ground System Freezing
- Why Do Freezes Have a Larger Impact?
- Factors to Consider from NH Lessons Learned
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New Horizons Introduction

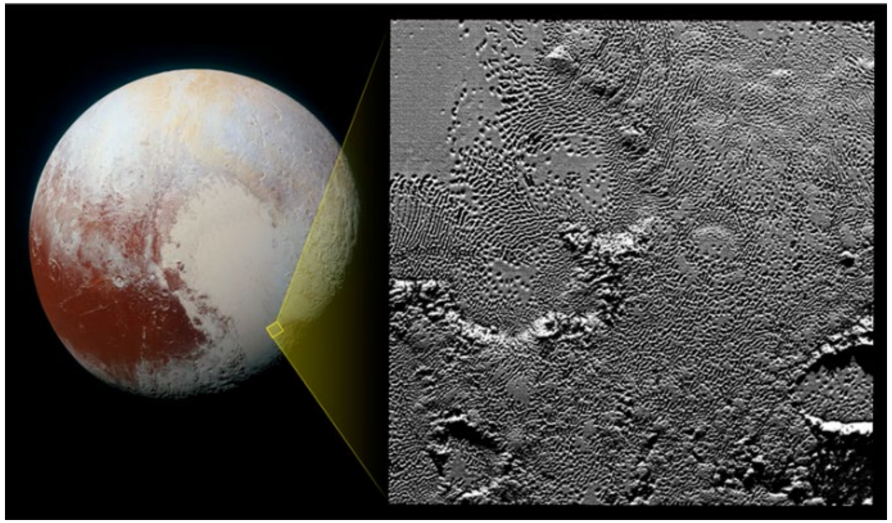
- The New Horizons (NH) spacecraft was the first mission to Pluto, completing the space-age reconnaissance of the planets that started 50 years earlier
  - It provided the first images of Pluto
  - It was also the first mission to explore the solar system's recently-discovered "third zone," the region beyond the giant planets called the Kuiper Belt.

- Mission timeline:
  - 2002 – APL development starts
  - 2005 – APL Integration and Test starts
  - 2006 – Launched on January 19
  - 2015 – Extremely successful flyby of Pluto on July 14
  - 2019 – Extremely successful flyby of Arrokoth on January 01
  - 2050 – Continued operations

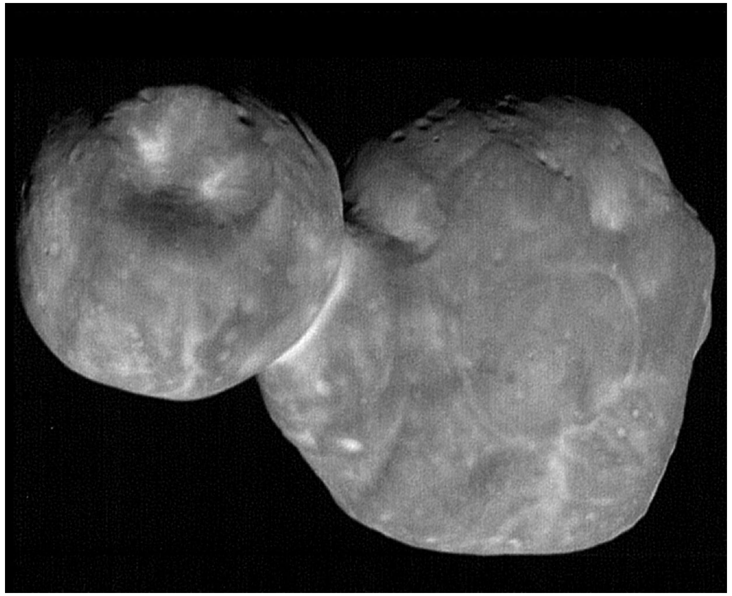
- Operations in the 2030s and beyond assumes an adjustment in the baseline power draw

- http://pluto.jhuapl.edu

Pluto: July 14, 2015



Arrokoth: January 01, 2019



The Challenge - Ground System Freezing

- Missions typically freeze the Ground System on a known good baseline prior to significant activities
  - For New Horizons, this occurred ~6 months before both the Pluto and Arrokoth flybys

- There are many valid reasons for a Ground System freeze:
  - Assures the tested versions match the operational versions for important activities
  - Limits the possibility of new changes breaking existing functionality
  - Reduces the number of changing variables when problems are encountered
  - Supports legacy hardware/software that cannot be easily updated
  - Conveys important activities to all members that support the Ground System, especially those who support multiple missions

- The challenge is when Ground System freezes are never lifted
  - “If it ain’t broken, don’t fix it” can be a very attractive policy to management

- A freeze adds “technical debt” the longer it is in place
  - Technical debt increases the complexity of making even trivial changes

Why Do Freezes Have a Larger Impact?

- A favorite question asked when discussing this topic is “what do older NASA missions do, such as Voyager?”

- There are three significant evolutions with technologies in a Ground System:
  - Hardware with a shorter life expectancy
    - In general, technology is moving towards cheaper solutions that expect to be replaced more frequently
  - Requirements that are continually updated or require continual updates
    - Information Assurance (IA) security is a great example
      - Vulnerabilities continue to be discovered, such as the log4j Critical vulnerability in 2021
  - Ground Systems are becoming more distributed
    - How many team members reside in locations off-site from the Ground System hardware?
      - How does the data get routed between the antenna and the Ground System?
      - Working from home as a result of COVID
        - Certainly was not part of the plan in Phases A-D
    - The Ground System then becomes dependent on the requirements / updates for each external interface

Factors to Consider from NH Lessons Learned

- The expected lifetime of a mission
  - If the spacecraft will run out of a critical resource in ~5 years, the risk of a freeze may be acceptable
    - For example, purchase a lifetime supply of hardware spares

- External interfaces should be expected to change, such as:
  - Interfaces with the Deep Space Network (DSN)
  - Interfaces with the Science Operations Center (SOC)
  - Protocol changes, such as FTP to SFTP

- Public-facing interfaces should be expected to change even more frequently, such as:
  - Websites
    - SOAP vs. REST
    - Version of HTML
    - Changes in Web browser support
  - Shared data centers, such as cloud-based storage

Factors to Consider from NH Lessons Learned

- End of Life plans for software languages used
  - Are major updates expected? Will new features in new versions be desirable to incorporate?
  - Will the language itself continue to exist?
    - Perl vs. Python
    - Will Matlab exist in the 2050s?
  - How will the development environment change?
    - IDEs
    - Compilers
    - Software Languages
    - Repository languages
  - Will new engineers be trained in these tools?
    - Do they teach Fortran in college?
    - Will they teach C++ in the 2050s?
    - Do they teach SVN in college? Will they teach GIT in the 2050s?

Factors to Consider from NH Lessons Learned

- End of Life for Hardware architecture and Operating Systems
  - SPARC vs. x86
  - Older operating systems cannot be installed on newer hardware
    - Windows XP, Solaris 6, etc
  - How long does the vendor support the product?
  - Is virtualization available? Does it meet performance needs?

- Security requirements
  - Do Operating Systems need to be patched?
  - Will older versions be allowed on the required networks?
    - Both internal networks and external networks, such as the NASA Restricted IONET
  - How do critical vulnerabilities get addressed?
    - Will these provided by a vendor?
    - Are these expected to be provided by the Ground System team?

- The need for a mission to react to unpredictable changes – technology changes quickly
  - Will Java even exist in 2050 or will it be viewed like Fortran?

Summary

- Many questions have been raised but there is no “right answer”
  - Each mission must assess their requirements, baseline technologies, risk posture, predicted lifespan
  - The point is to ask the question and revisit the decision as needed
    - Which is preferable: updating hardware or performing a lifetime purchase of spares?

- Imagine having to define the following, which will be used in 50+ years:
  - Integrated Development Environment (IDE)
  - Bug tracking system
  - Hardware architecture platform
  - Third party tools
  - External Interface Control Documents (ICDs)
  - Security posture

- How can future engineers, who have not even finished high school, or in some cases aren’t even born yet, be responsible for maintaining this baseline?

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