Computing for the Space Program

R. Mazzone
NASA KSC
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Overview

- The UNIVAC was the typical computer when NASA was founded in 1958
- Reliance on computers for space missions has increased over time:
  - Mercury program didn't have a computer on board
  - Apollo became the first manned program to use computers continuously in all mission phases
  - Space Shuttle could not have functioned without computers
- The evolution of computer technology itself has enabled more versatility in space missions
  - Spacecraft carry more computers, have more processing power, can perform more complex tasks, and require less human intervention
- Today software supports all phases of mission design, planning, development and execution - both in space and on the ground - for all manned and unmanned missions
- **Simply put: Without computers, spaceflight as we know it today would not be possible.**

References:
http://history.nasa.gov/computers/contents.html

Pleiades

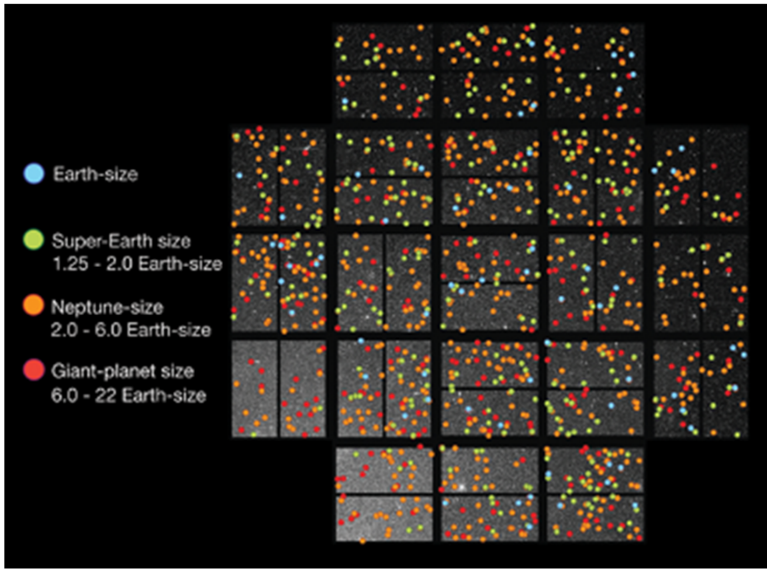
- **Manufacturer: SGI**
- **185 racks (11,776 nodes)**
- **1.34 Pflop/s peak cluster**
- **1.09 Pflop/s LINPACK rating (June 2011, using 11,648 nodes)**
- **2 racks (64 nodes total) enhanced with NVIDIA graphics processing unit (GPU): 43 teraflops total**
- **Total cores: 112,896 (32,768 additional GPU cores)**
- **Total memory: 191 TB**

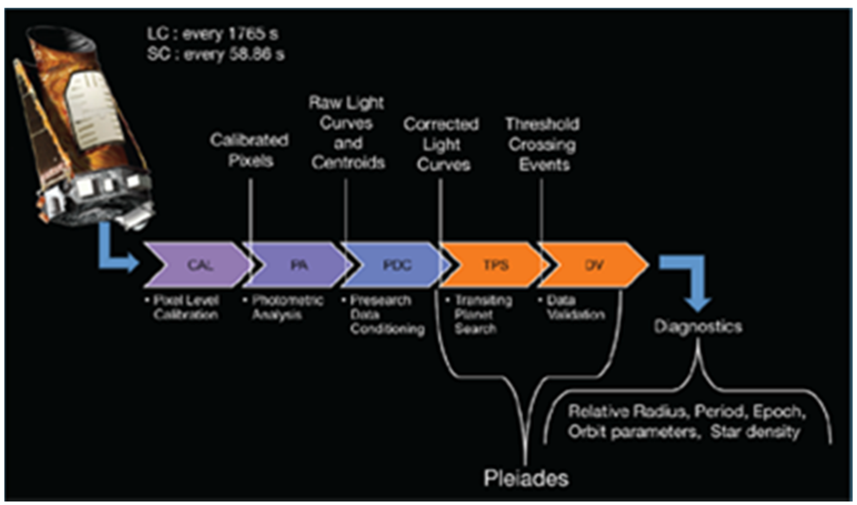
This summer Pleiades was ranked the 7th most powerful, high performance computer in the world.

References:

http://www.nas.nasa.gov/hecc/resources/pleiades.html

Kepler Analysis



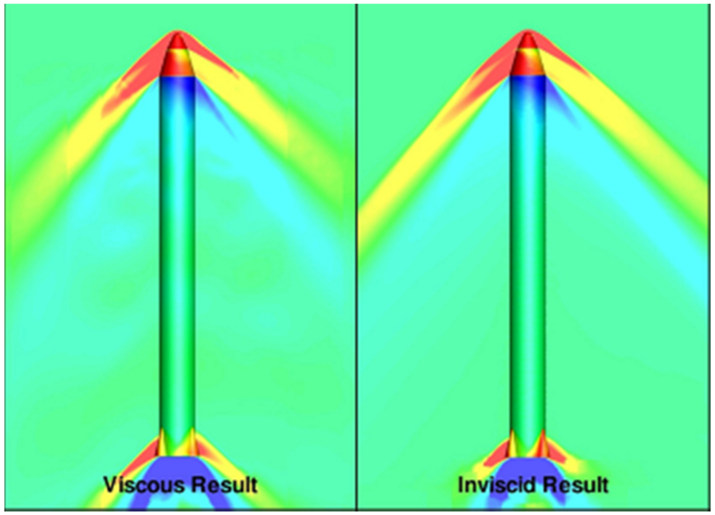


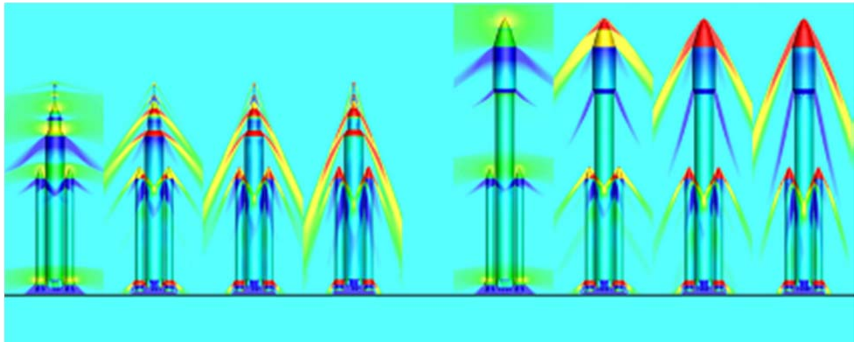
- **Launched in March 2009, the Kepler spacecraft is continuously monitoring over 150,000 stars in the constellations of Cygnus and Lyra, watching for the periodic dimming that may indicate the presence of an exoplanet passing in front of a star.**

- **The scientific goal of the Kepler mission is to explore the structure and diversity of planetary systems. We achieve this by surveying a large sample of main-sequence stars to:**
  - **Determine the frequency of terrestrial and larger planets in or near the habitable zone of a wide variety of star types**
  - **Determine the distributions of planet-sizes and their orbital semi-major axes**
  - **Estimate the frequency and orbital distribution of planets in multiple-star systems**
  - **Determine the distributions of the semi-major axis, albedo, size, mass, and density of short-period giant planets**
  - **Determine the properties of stars that harbor planetary systems**

Sources:
Todd C. Klaus, Joseph D. Twicken; NASA Ames Research Center; Science Mission Directorate

Computational Fluid Dynamics



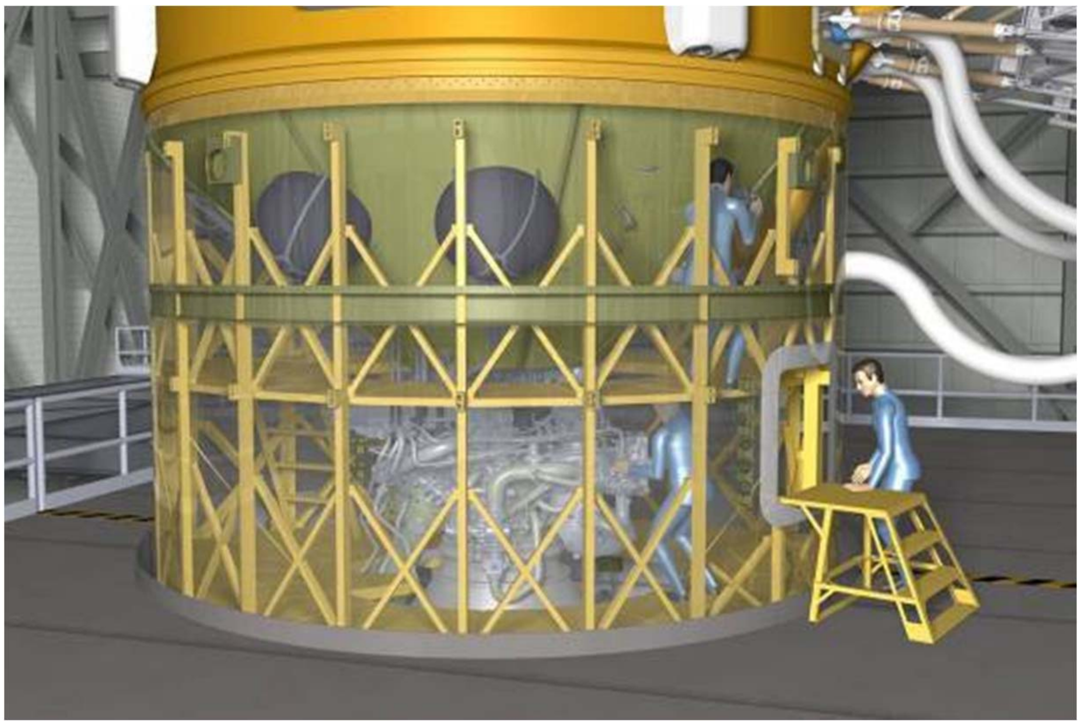


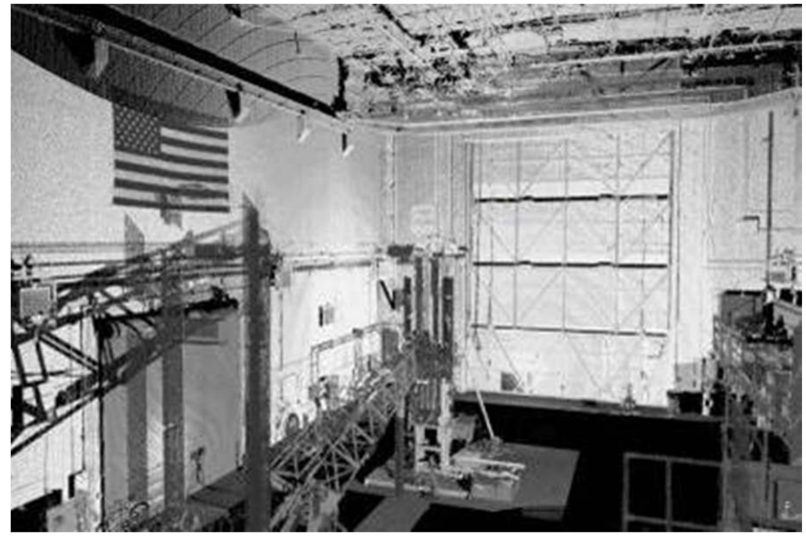
- **Modeling and simulation experts are performing computational fluid dynamics (CFD) simulations supporting the design of NASA's next-generation, heavy-lift Space Launch System (SLS). Studies to date include:**
  - **Initial shape trade studies to help assess and compare alternate SLS designs developed at several NASA Centers**
  - **Inviscid aerodynamic performance characterization for both crew and cargo versions of SLS vehicle designs**
  - **Viscous analysis of an early SLS design concept**
  - **Computation of line loads and surface pressure signatures throughout ascent for preliminary SLS designs**
- **Results from these analyses enable designers and engineers to optimize the vehicle's shape for better performance, and to assess the structural and acoustic loads that the vehicle will encounter during ascent.**

Sources:
Cetin Kiris, Jeffrey Housman; NASA Ames Research Center; Human Exploration & Operations Mission Directorate

3-D Modeling & Simulation

Operations Planning for Vehicle Processing





Model generated from Laser Scanning Data

Mars Science Laboratory Ground Ops Planning

2008

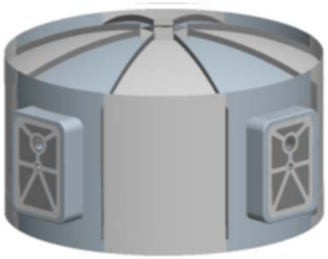
2008

2011

2011

HDU: Concept to Test Article

January 2009



June 2009

May 2010

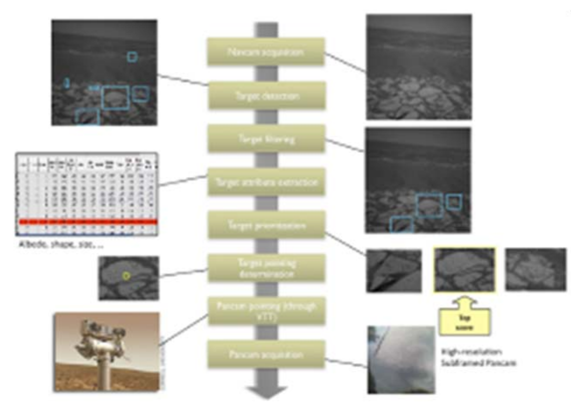
September 2010

Virtual Reality

The Virtual Reality Lab at JSC is an immersive training facility that provides real time graphics and motion simulators integrated with a tendon-driven robotic device to provide the kinesthetic sensation of the mass and inertia characteristics of any large object (<500lb) being handled.

References:
http://www.nasa.gov/centers/johnson/engineering/robotics_simulation/virtual_reality/index.html
http://www.foxnews.com/scitech/2011/07/12/astronauts-train-for-space-walk-in-virtual-reality-lab/

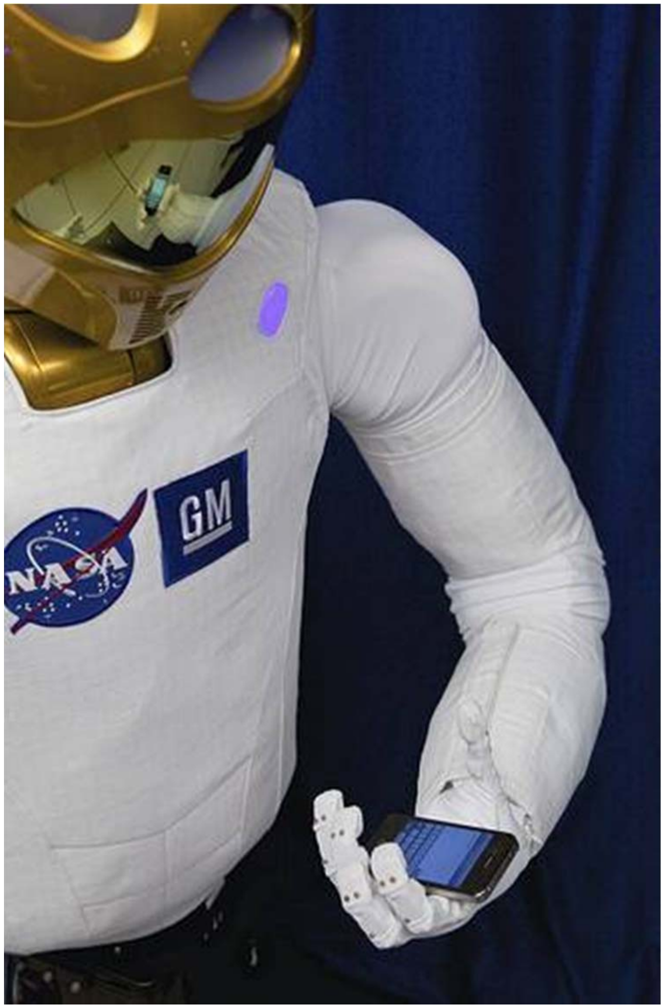
Artificial Intelligence



The Autonomous Exploration for Gathering Increased Science (AEGIS) system enables automated data collection by planetary rovers. AEGIS software was uploaded to the Mars Exploration Rover (MER) mission's Opportunity rover in December 2009 and continues to successfully demonstrate automated onboard targeting based on scientist-specified objectives. AEGIS was named NASA's Software of the Year for 2011.

References:
http://aegis.jpl.nasa.gov/
http://marsrovers.jpl.nasa.gov/gallery/press/opportunity/20050506a.html

Robotics



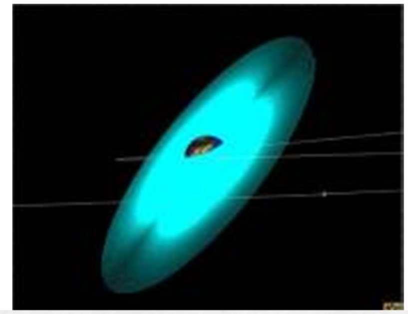
- **Robonaut2 (R2) is a state of the art highly dexterous anthropomorphic robot; R2B is currently on the International Space Station (ISS)**
- **R2's control system is challenged by many requirements that cannot be met with only classical robot control methods**
  - **provide safe, reliable control for 47+ degrees-of-freedom**
  - **be controllable via direct teleoperation, shared control, and full autonomy**
  - **maintain performance in a harsh thermal environment**
  - **execute at the required rate on reasonable hardware**

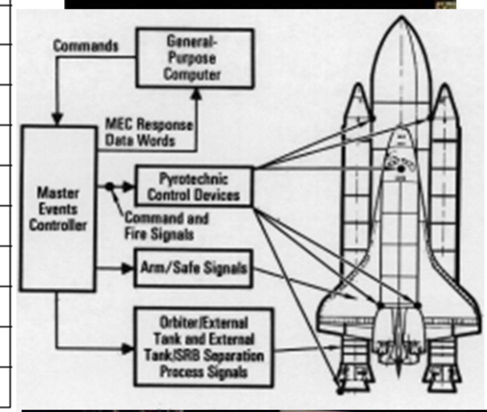
References:
http://www.flickr.com/photos/nasarobonaut/
http://robonaut.jsc.nasa.gov/R1/sub/software.asp

Flight Software

Functionality implemented in flight software in the past (green), planned (brown), and future (red).

Command sequencing	Guided descent & landing	Parachute deployment
Telemetry collection & formatting	Trajectory & ephemeris propagation	Surface sample acquisition and handling
Attitude and velocity control	Thermal control	Guided atmospheric entry
Aperture & array pointing	Star identification	Tethered system soft landing
Configuration management	Trajectory determination	Interferometer control
Payload management	Maneuver planning	Dynamic resource management
Fault detection & diagnosis	Momentum management	Long distance traversal
Safing & fault recovery	Aerobraking	Landing hazard avoidance
Critical event sequencing	Fine guidance pointing	Model-based reasoning
Profiled pointing and control	Data priority management	Plan repair
Motion compensation	Event-driven sequencing	Guided ascent
Robot arm control	Relay communications	Rendezvous and docking
Data storage management	Science event detection	Formation flying
Data encoding/decoding	Surface hazard avoidance	Opportunistic science



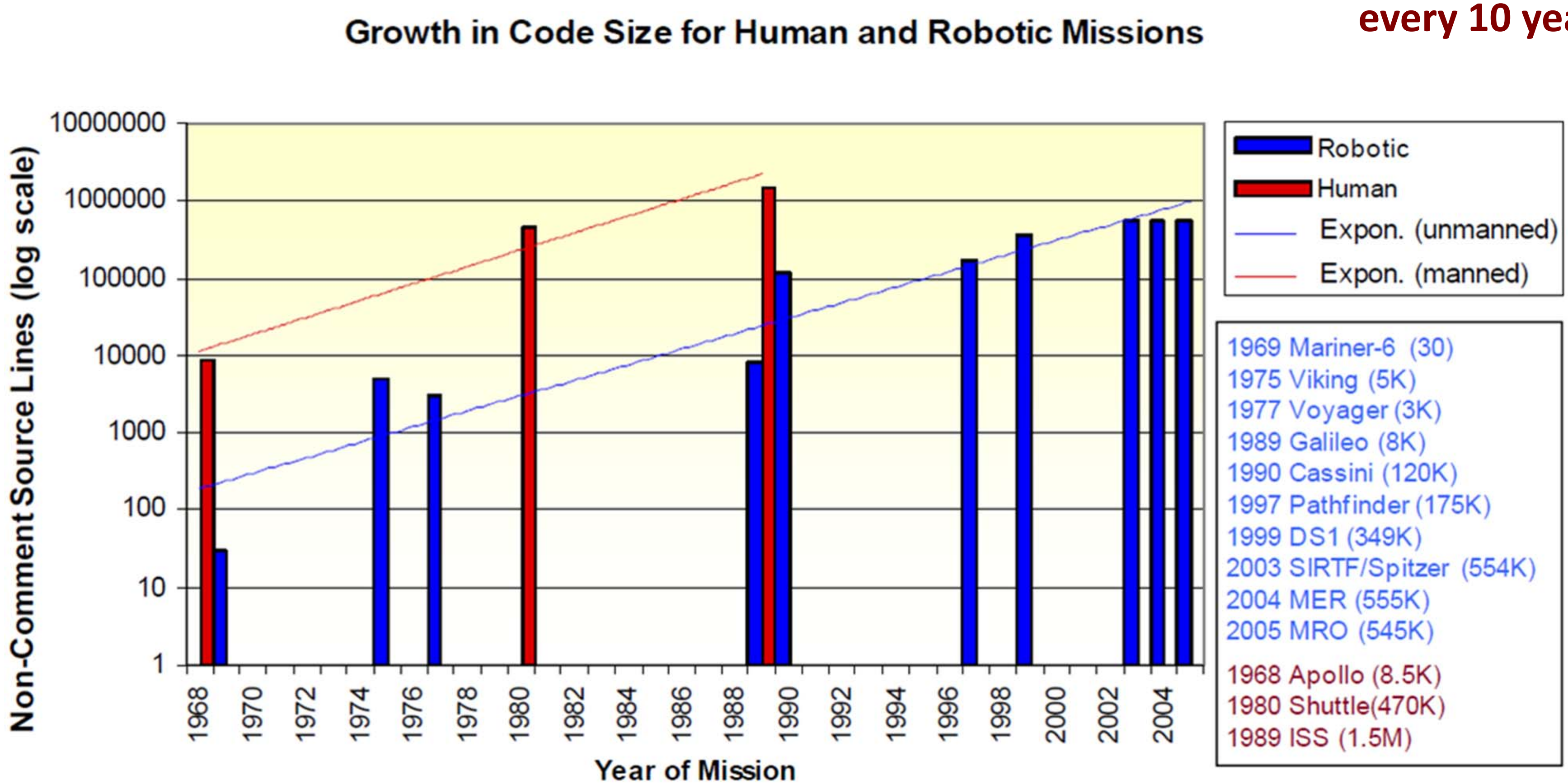


"Flight software has become a spacecraft's 'complexity sponge' because it readily accommodates evolving understanding, making it an enabler of progress."

References:
NASA Study on Flight Software Complexity, Office of the Chief Engineer, 2007
http://science.ksc.nasa.gov/shuttle/technology/images

Looking Forward

"software grows by an order of magnitude every 10 years"



"As missions change and become more complex, using software to adjust for the changes is much cheaper and faster than changing the hardware."

References:

NASA Study on Flight Software Complexity, Office of the Chief Engineer, 2007


Imagine where computing will take us next…