OpenSpace
Public Dissemination of Space Mission Profiles

Alexander Bock[1], Michal Marcinkowski[1,2], Joakim Kilby[1], Carter Emmart[2], and Anders Ynnerman[1]

[1] Department of Science and Technology, Linköping University
[2] American Museum of Natural History, New York

Open-Source (MIT license)
GitHub: https://github.com/OpenSpace
http://openspace.itn.liu.se

OpenSpace

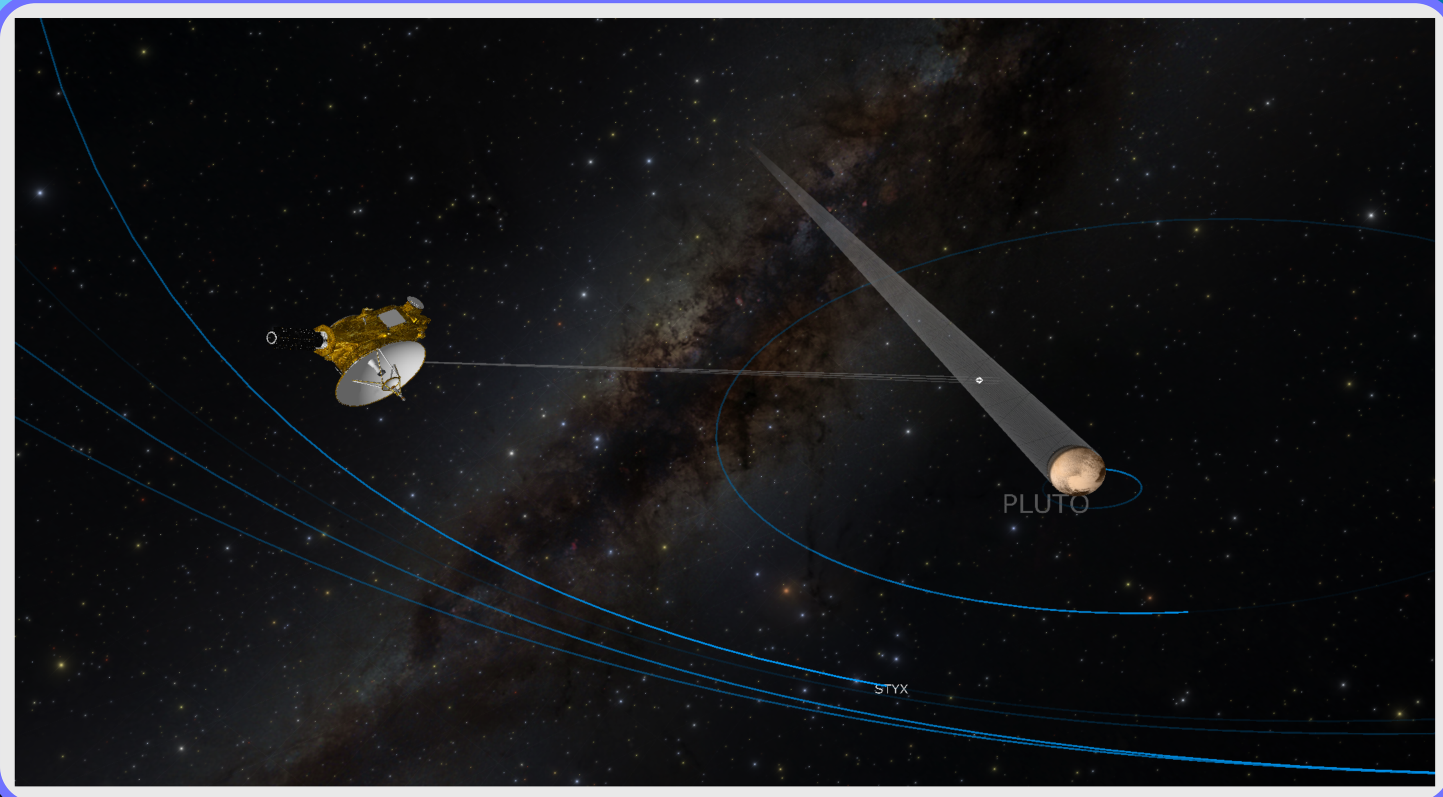
- Collaborative open-source development focused on large-scale, contextualized, multimodal astrovisualization
- Support for single pipeline (laptop, desktop computers) or cluster rendering (planetariums, power walls, ...)
- Rendering of geometric and volumetric data using order-independent transparency based on A-Buffers [1]
- Extensible modular software architecture
- Accurate representation of three dimensional trajectories in the solar system using NASA's SPICE library
- "DomeCasting" capability to perform synchronized one-to-many connected renderings
- Recording of flights for later playback

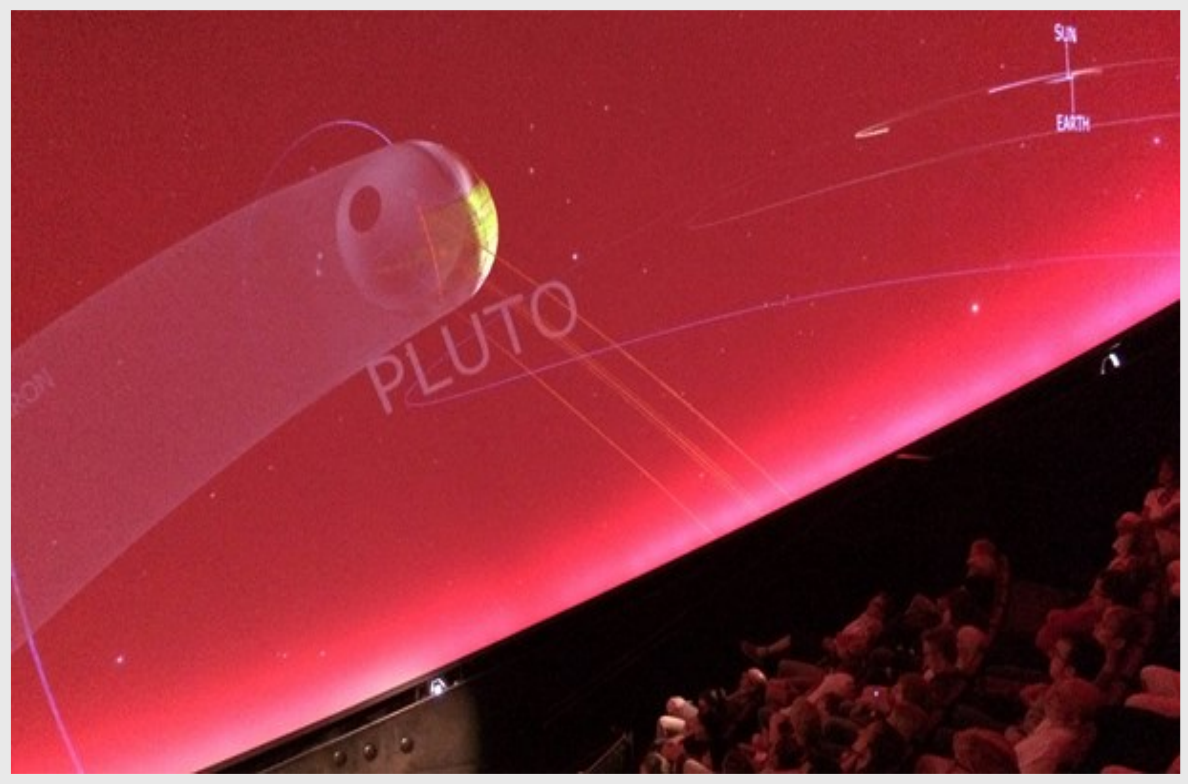
Goals

Space missions, such as New Horizons, are very expensive endeavors carried out in the public interest. These missions are planned years or decades in advance in order to maximize scientific output. Due to the lack of available tools for the general public, the spacecraft's actions during this exploration can be difficult to understand and communicate. However, the public at large needs to be informed and educated in order to acknowledge the usefulness of this expense. In our system, we present visualizations to allow the public insight into the mission profiles of select missions and understand the maneuvers and the scientific experiments that are performed. This not only allows the mission scientists to explain their findings in context, but it also allows them to preview different mission plans, while providing interesting content for the public to support future funding.

Image Projection

One of the main scientific instruments used on spacecraft are digital cameras that take images. In order to visualize these images, they are projected onto the respective target body by using the projective texturing approach as described by Everitt et al [2]. In the cases where the entire image does not cover a body, a virtual image plane is added that contains the remainder of the image.





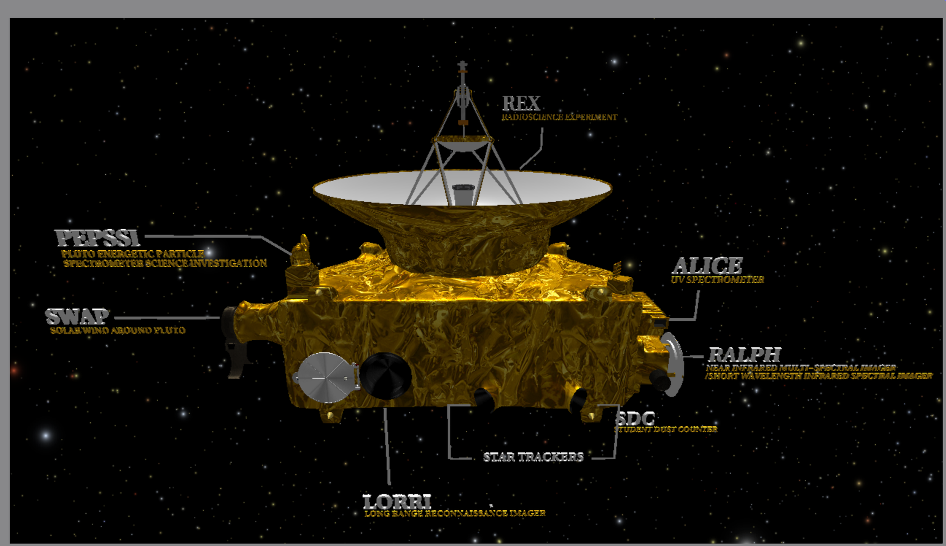
New Horizons

- Launched in 2006 from Cape Canaveral
- Fly-by of Jupiter in 2007
- Fly-by of Pluto on July 14th, 2015
- Selection of on-board instruments:
  - Long Range Reconnaissance Imager (LORRI)
  - Ralph (Multispectral imager)
  - Radio Experiment (REX)

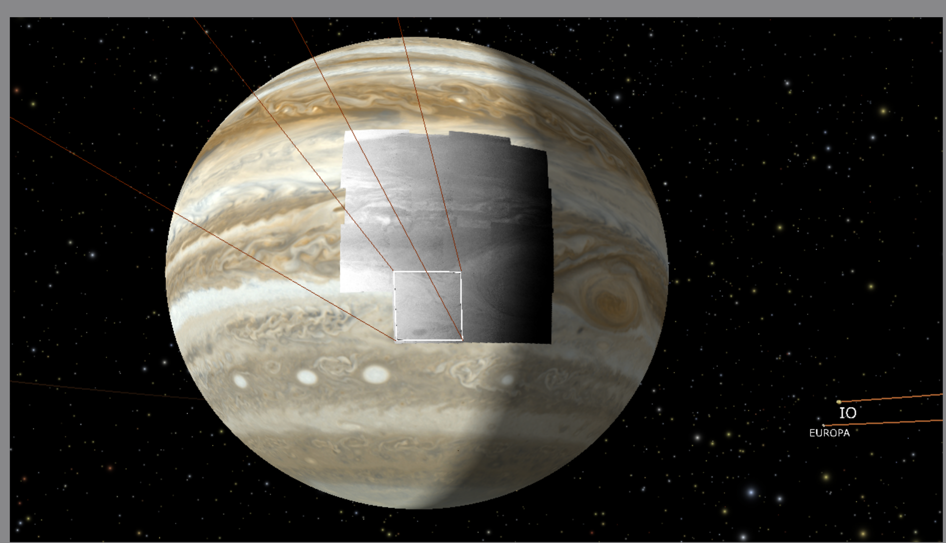
In our system, images from LORRI and Ralph are shown on the planetary bodies (Jupiter, Pluto, Charon, and other moons) using the projective texturing method, while the REX's occultation measurements are represented by a line connecting the spacecraft and Earth. By presenting the images in this way, the complex maneuvers of the spacecraft, which are required for the image acquisition are illustrated to the public.

The components for this mission were shown at the American Museum of Natural History's "Evening for Educators" event on May 14th which was part of the Pluto Palooza series. Several hundred teachers participated in this event during the course of a day.

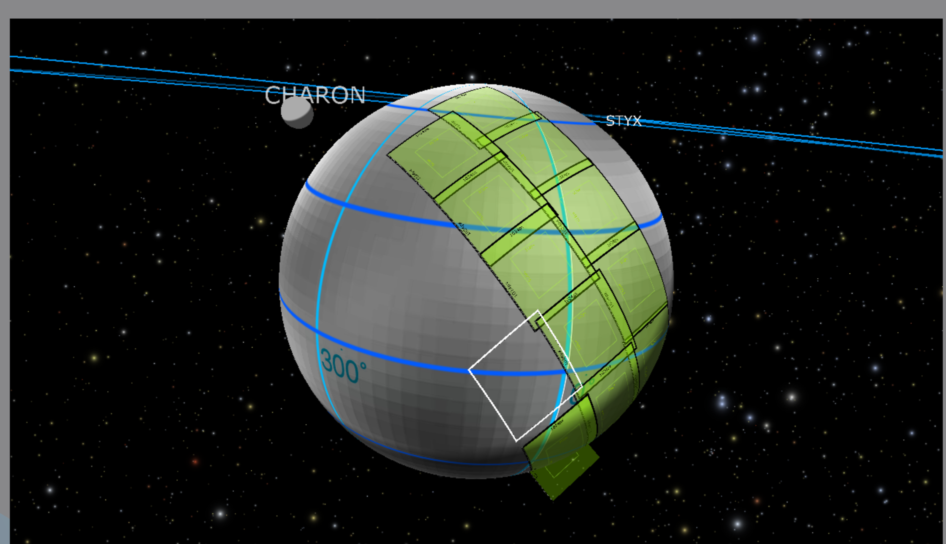
In addition, on July 14th 2015, the fly-by was shown simultaneously at 12 planetariums around the globe during the 2 hours of closest approach using the DomeCasting technique. During this "Breakfast at Pluto" event, selected mission scientist explained to a live audience of about 1000 people what their experiments were doing at that moment using simulated output from our system. This event was streamed live to an additional audience of up to 1000 viewers on Youtube. Currently, this video has received in excess of 50000 views in total.



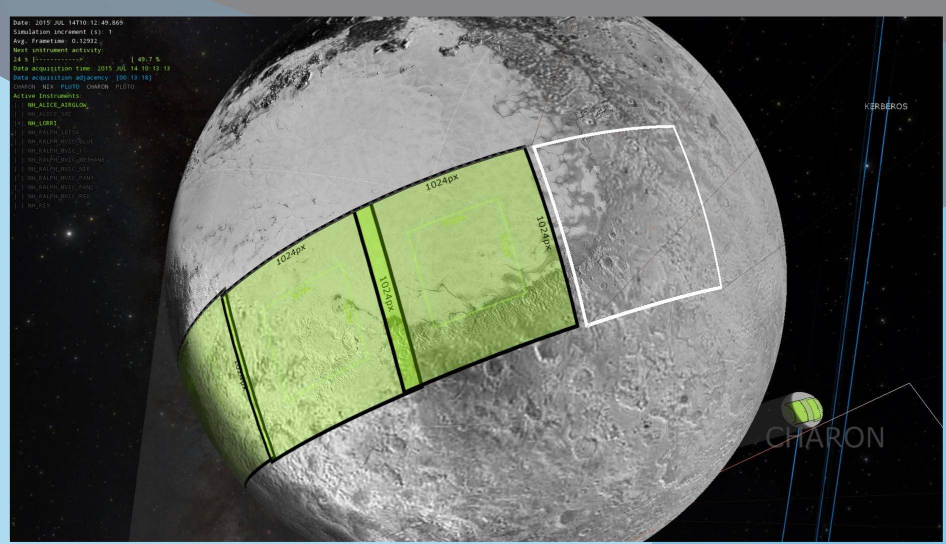
The New Horizons spacecraft with all instruments



A 4x4 image mosaic of LORRI taken on Jupiter in 2007



A LORRI image sequence on Pluto on July 14th, 2015

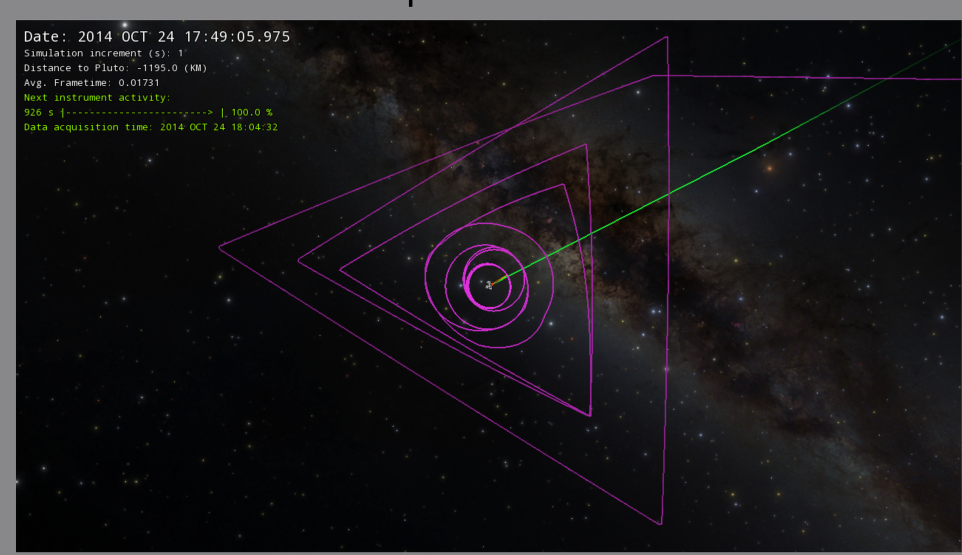


A close-up on Tombaugh Regio ("The Heart") on Pluto

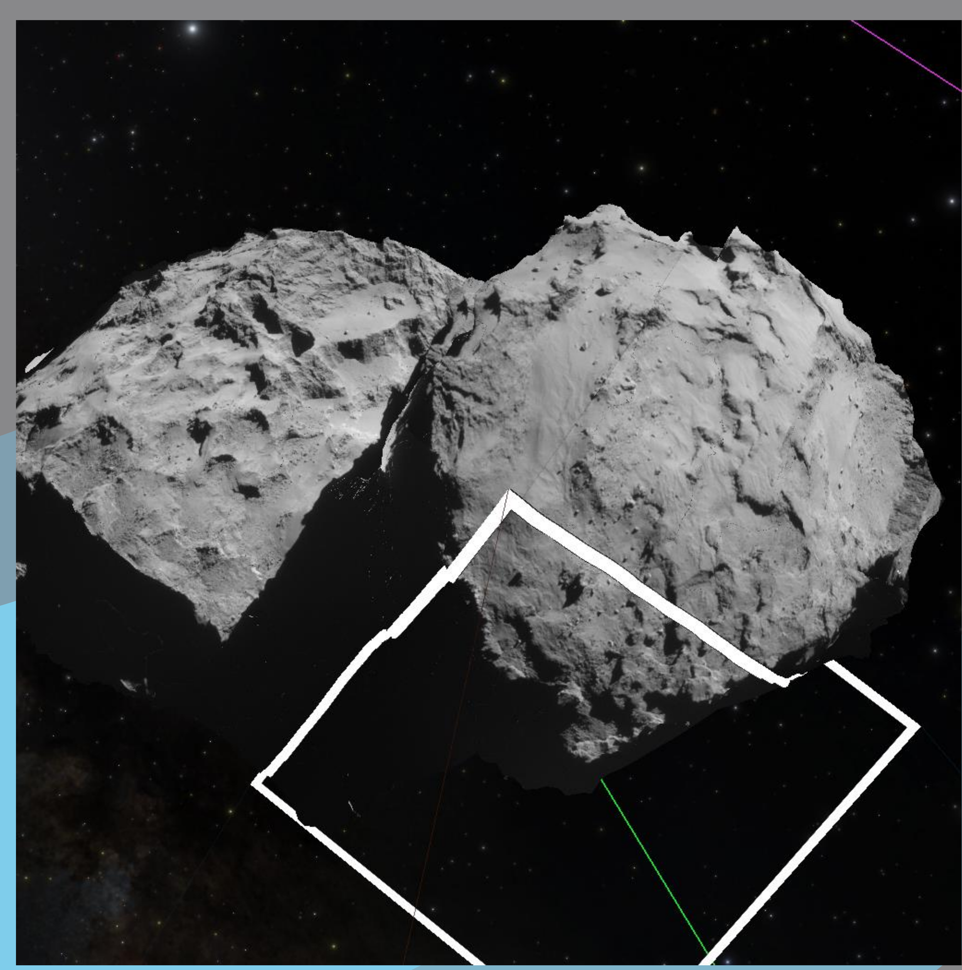
Rosetta

- Launched by ESA in 2004 from French Guiana
- Arrived at comet 67P Churyumov-Gerasimenko on August 6th, 2014
- Images taken by the NAVCAM instrument

Compared to other space missions, the trajectory of the spacecraft is quite complex, as the mass of the comet had to be measured before an orbit could be established. Rosetta is currently orbiting the comet, flying as close as 6km, taking measurements and images from the surface. In our system, we show the trajectory and project the NAVCAM images onto an accurate shape model to increase the graphical fidelity of the comet 67P. This allows users to see details on the comet's surface and comprehend its structure and rotation.



The initial trajectory and orbit of Rosetta around 67P

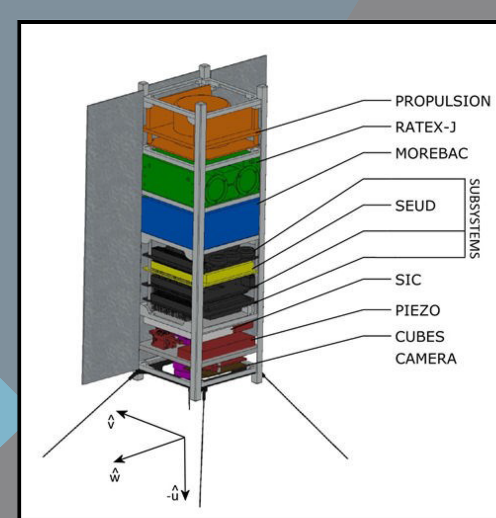


A close-up image taken by Rosetta's NAVCAM instrument

MIST

- 3U cubesat (30cm x 30cm x 10cm)
- Developed by KTH Royal Institute of Technology, Sweden
- Scheduled to launch in 2017
- High definition camera instrument to monitor the Earth

We are developing the camera setup and the in-flight visualization software the MIST student satellite. By simulating the camera output from the projected trajectory in our system, we optimize the location and attributes of the camera in the satellite. As the goal of this camera is to take images of Earth, these simulations are useful to determine the desired field-of-view and, eventually, estimate adequate exposure times. Since the available bandwidth for the satellite is below 1kbit/s, we are utilizing a learning-based image reconstruction technique by Miandji et al. [3] to reduce the data that needs to be downlinked. The images necessary for the training phase of this algorithm will also be generated by this system at a later stage.



A possible configuration for the MIST cubesat

[1] S. Lindholm, M. Falk, E. Sundén, A.Bock, A. Ynnerman, and T. Ropinski. Hybrid Data Visualization Based on Depth Complexity Histogram Analysis. *Computer Graphics Forum*, 2014
[2] C. Everitt, A. Rege, and C. Cebenoyan. Hardware Shadow Mapping. *Nvidia white paper*, 2001
[3] E. Miandji, J. Kronander, and J. Unger. Compressive image reconstruction in reduced union of subspaces. In *Eurographics 2015*, May 2015

Linköping University
NORRKÖPING VISUALIZATION CENTER
American Museum of Natural History