DigitalSpace

QSS 8317-DIG-002 (Task 228)

Final Report on Phase II

* DRAFT *

Introduction

The original phase II statement of work called for DSS work to model:

1. Microsat Autonomy demonstration/surface interaction visualization.
2. Use of CLV RCS during launch abort;

Due to the cancellation of all Lunar Microsat activity at NASA ARC the task requestor, Mark Shirley, asked us to produce *models of the Constellation launch vehicles*. In addition, he requested us to *complete the scripting interfaces within the DSS platform*. New opportunities both in the commercial sphere and at NASA arose that allowed us to complete both of these tasks. These will be described next and constitute our final delivery of the work contracted under this agreement.

The two elements of this report are therefore:

1. **DSS Modeling of a Constellation/Orion NEO Mission**
2. **DSS Scripting Interface**

1) DSS Modeling of a Constellation/Orion NEO Mission

The original SOW called for *implementation of extensions required to enable DSS to be used for visualizations supporting quick-look trade studies for assessing potential exploration vehicle configurations*. In the Fall of 2006 NASA commissioned a trade study on the use of the Constellation architecture to perform a human sortie/exploration mission of one or more Near Earth Objects (NEOs). In September of that year DigitalSpace was approached by Rob Landis of NASA JSC asking for help in visualizing such a mission. When the formal trade study was initiated by NASA HQ, we contacted Rob about supporting the study. Rob accepted our offer and DigitalSpace obtained approval by Mark

Shirley to engage in this work as a part of the deliverable for this QSS agreement. We will now present the results of this work which consist of visualization (all still images derived from 3D modeling work) used internally by the trade study. We hope that this work will be utilized in further phases of possible NEO mission studies.

Step 1: Conceptual Design

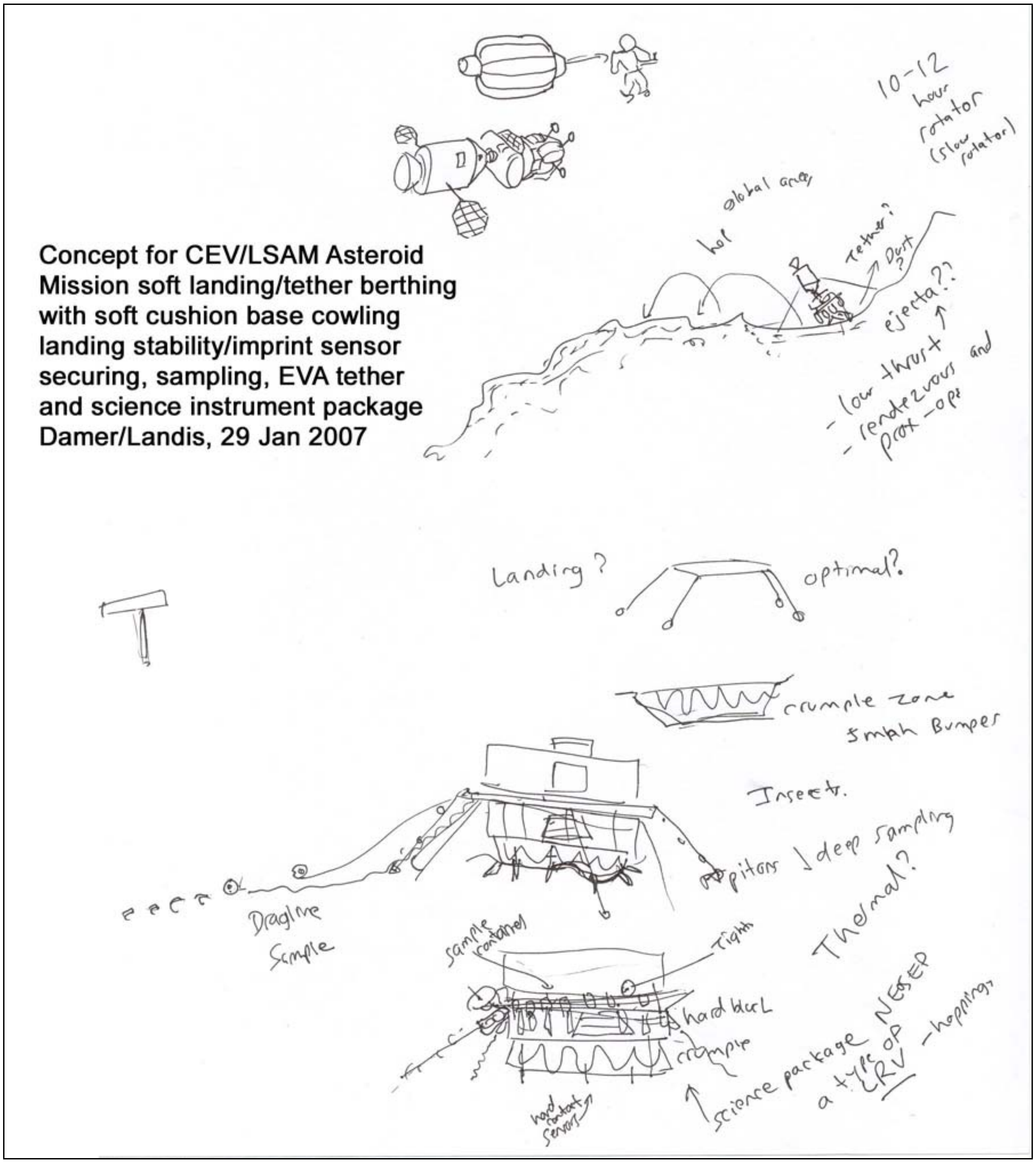

Fig 1: concept sketches Damer/Landis 29 Jan 2007

DigitalSpace's involvement in the NEO trade study was at a distance via Rob Landis, co-lead from JSC. His other co-lead was Dave Korsmeyer from NASA ARC. Two visits from Rob Landis helped us cement understanding of the challenge, which we took to be:

1. Depicting the launch vehicles, orbit/rendezvous and TNI to the target
2. Depicting notions of "berthing" with the NEO

The sketch in Figure 1 above is representative of a "soft tether berthing" approach utilizing airbags, harpoon tethers and bearing capacity sensors in a ring attached under a modified Lunar Surface Access Module (LSAM) called the NEO Surface Access Module (NSAM). DigitalSpace produced its most detailed visualization of this notional berthing concept with the NSAM (see Step 5 below).

Step 2: Configuring the launch vehicles and exploration stack

The first stage of this project was to select and model the launch vehicles. Initially we were given the task of depicting Ares IV, a slightly lighter weight configuration of Ares V that carries the CEV (Orion) and additional hardware for the construction of the NEO mission stack. Figures 2-3 below show the Ares IV.

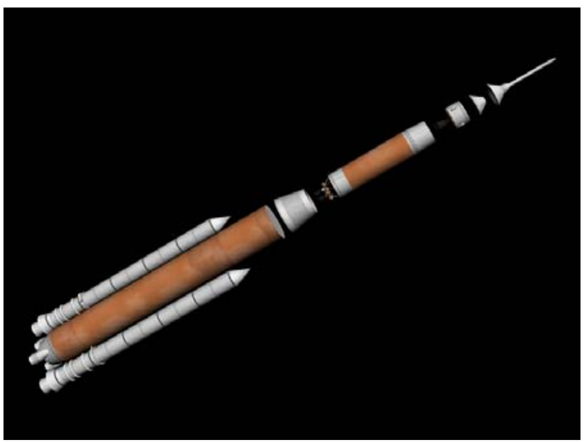

Fig 2: Ares IV in segments (for Orion launch)

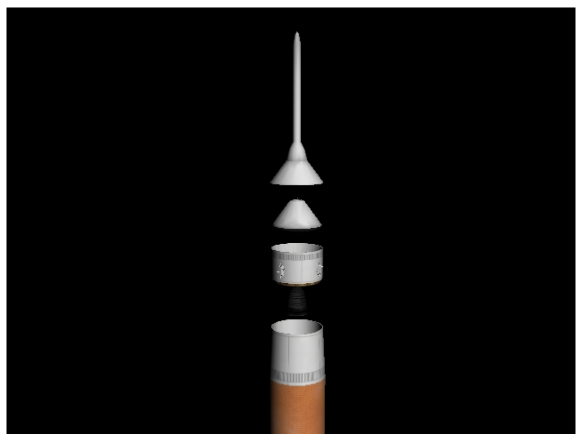

Fig 3: Ares IV Orion stack

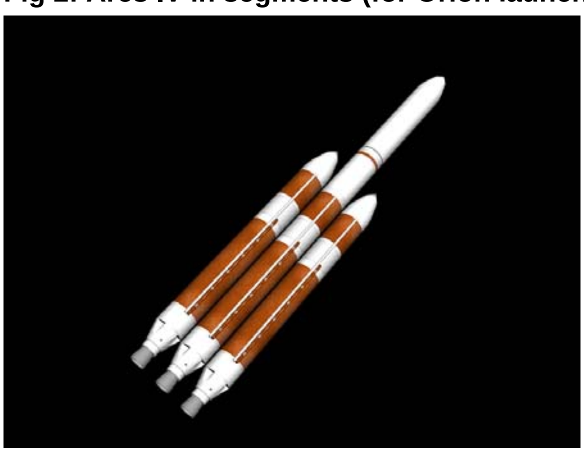

Fig 4: Delta IV Heavy

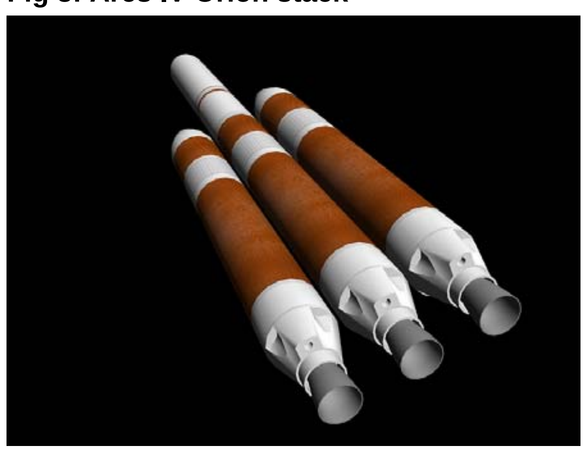

Fig 5: Delta IV Heavy

Next was the concept of using an EELV (Atlas V or Delta IV Heavy) to carry a Centaur Upper Stage to orbit, for rendezvous and docking with the Orion NEO stack which would then be propelled to the NEO. Figures 4-5 above depict our model of the Delta IV Heavy. Later we were requested to switch to showing Ares V carrying an Earth Departure Stage (EDS).

Step 3: Launch and on-orbit assembly of stack

Fig 6: Delta IV Heavy delivering the Centaur Upper Stage

Figure 6 above depicts an earlier concept of EELV Delta IV Heavy delivering the Centaur Upper Stage to LEO. Figure 7 below depicts the later concept of Ares V delivering an Earth Departure Stage to LEO.

We will now depict our modeling of the on-orbit assembly of the mission stack, followed by Trans Neo Injection (TNI), coast, arrival at the target, berthing at the NEO surface, surface operations and departure and Earth return (see Figures 7-27 below).

Fig 7: Ares V launch of Earth Departure Stage

Figure 8 below depicts Ares IV delivering CEV (Orion) to LEO.

Fig 8: Ares IV launch of CEV

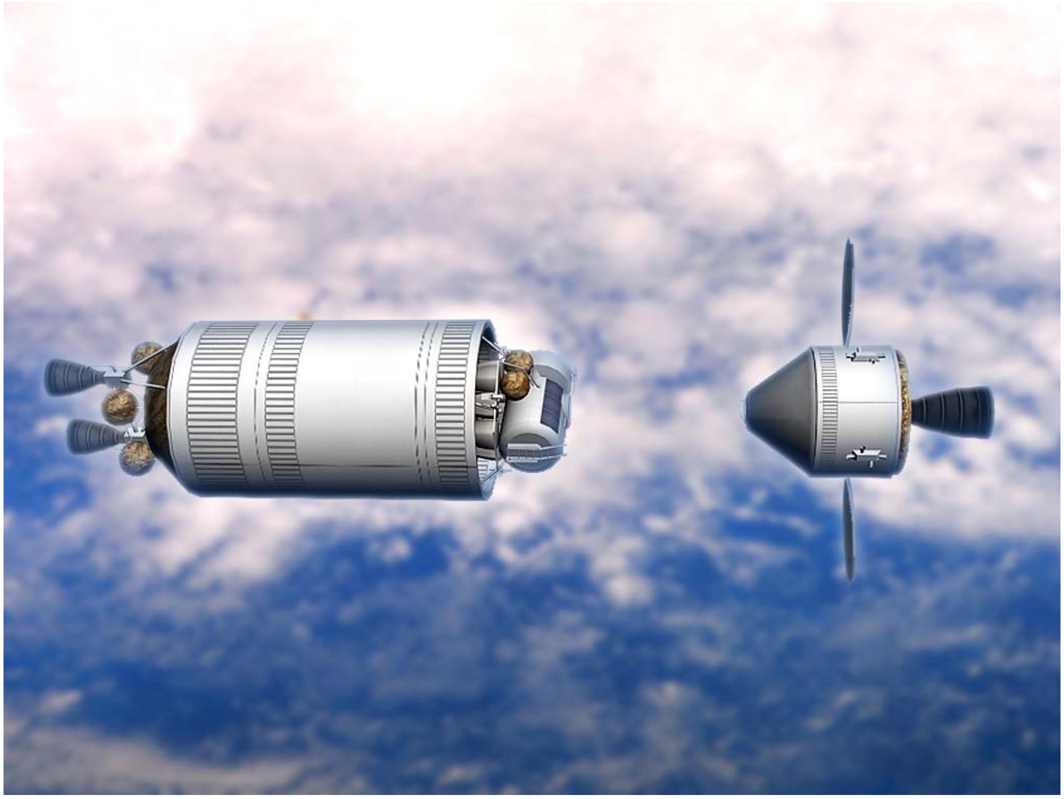

Fig 9: Orion rendezvous and docking with Earth Departure Stage

Fig 10: Complete stack for TNI

Step 4: Trans NEO Injection (TNI), coast and arrival at target

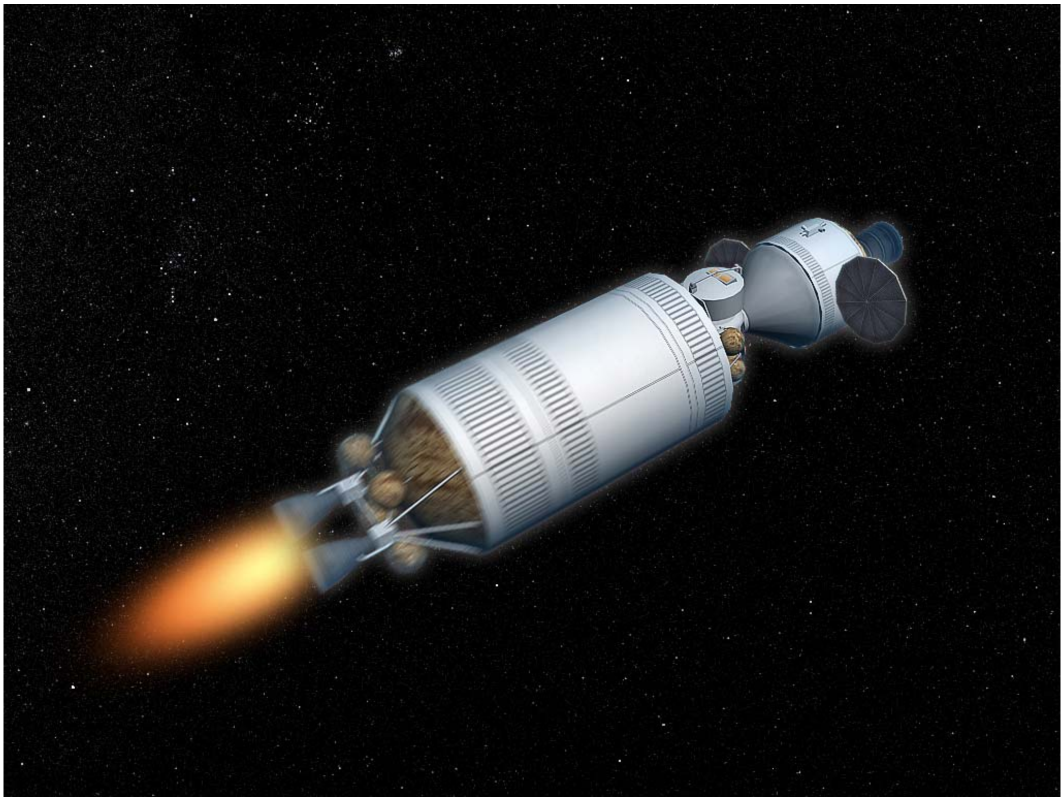

Fig 11: TNI Burn

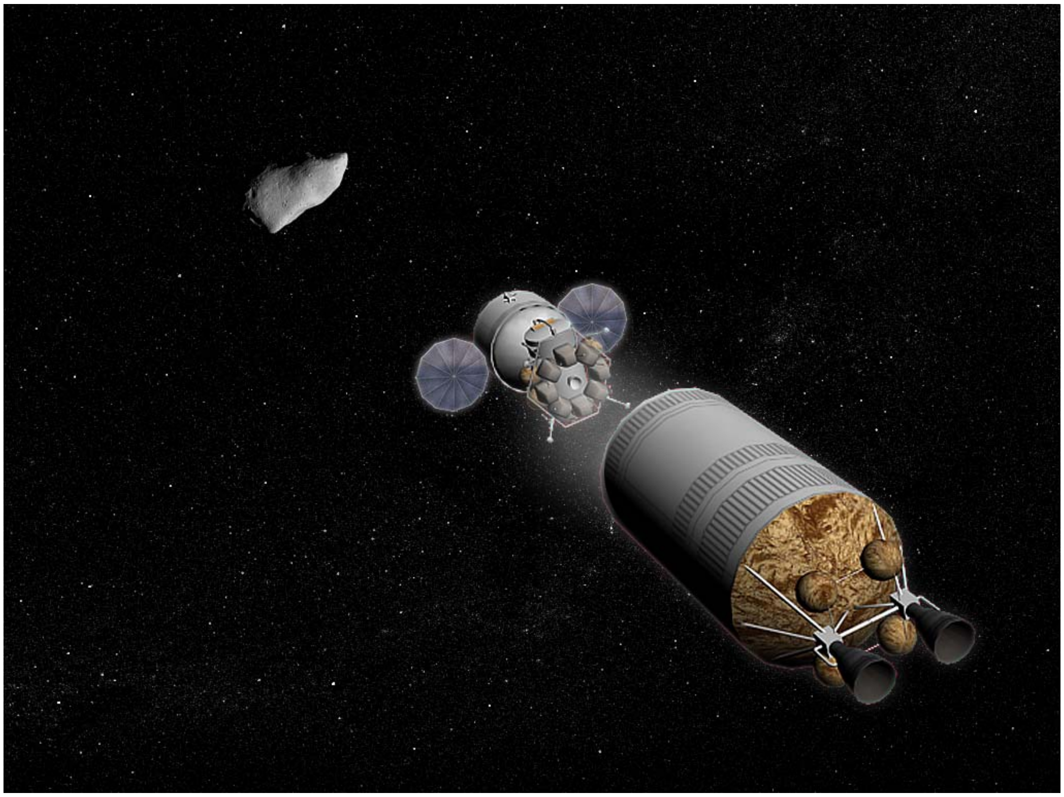

Fig 12: EDS Separation on approach to NEO target

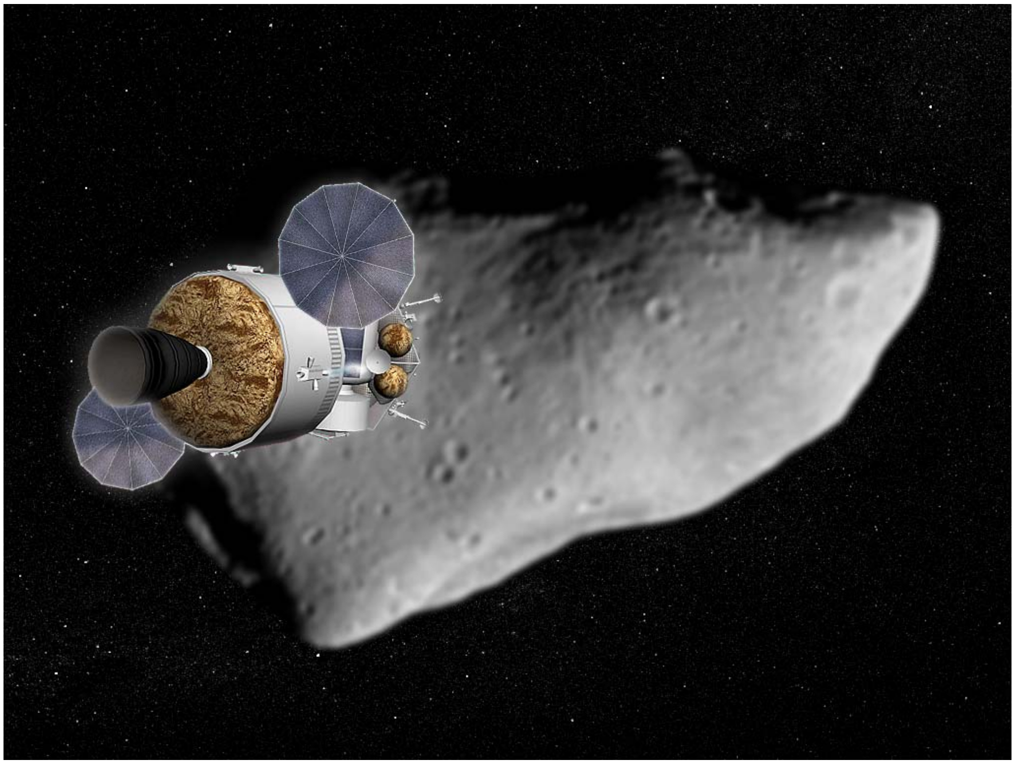

Fig 13: Arriving and station keeping at NEO target

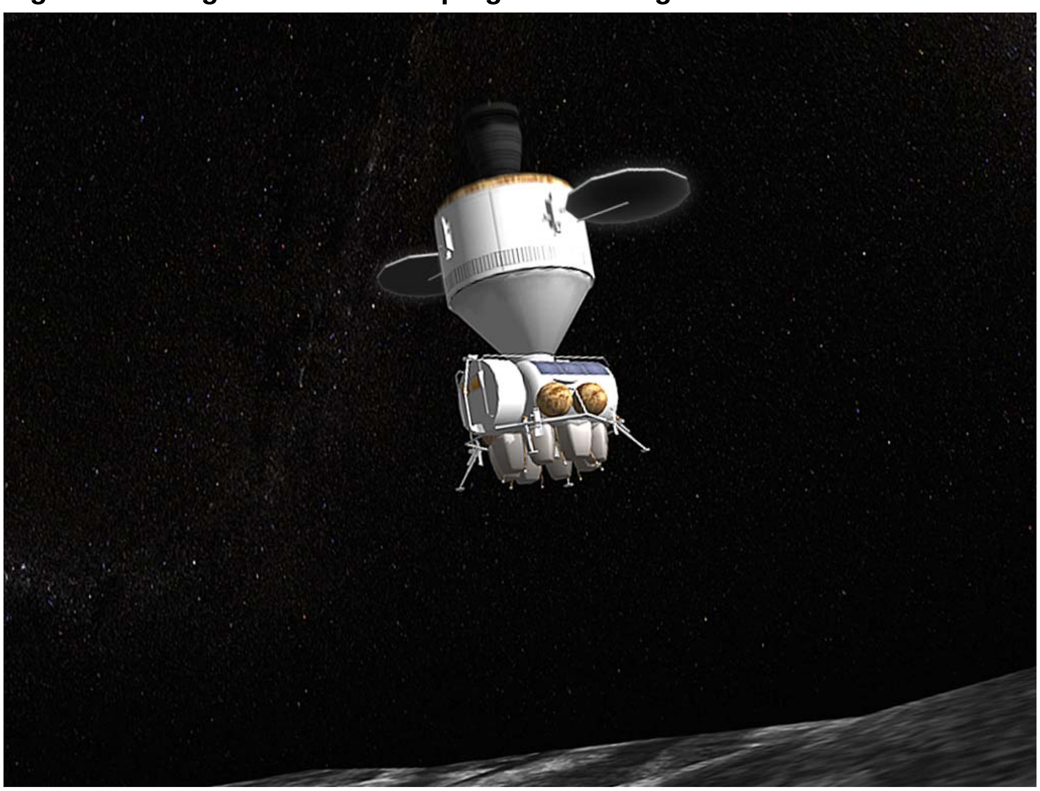

Fig 14: NEO close approach

Step 5: Berthing at NEO

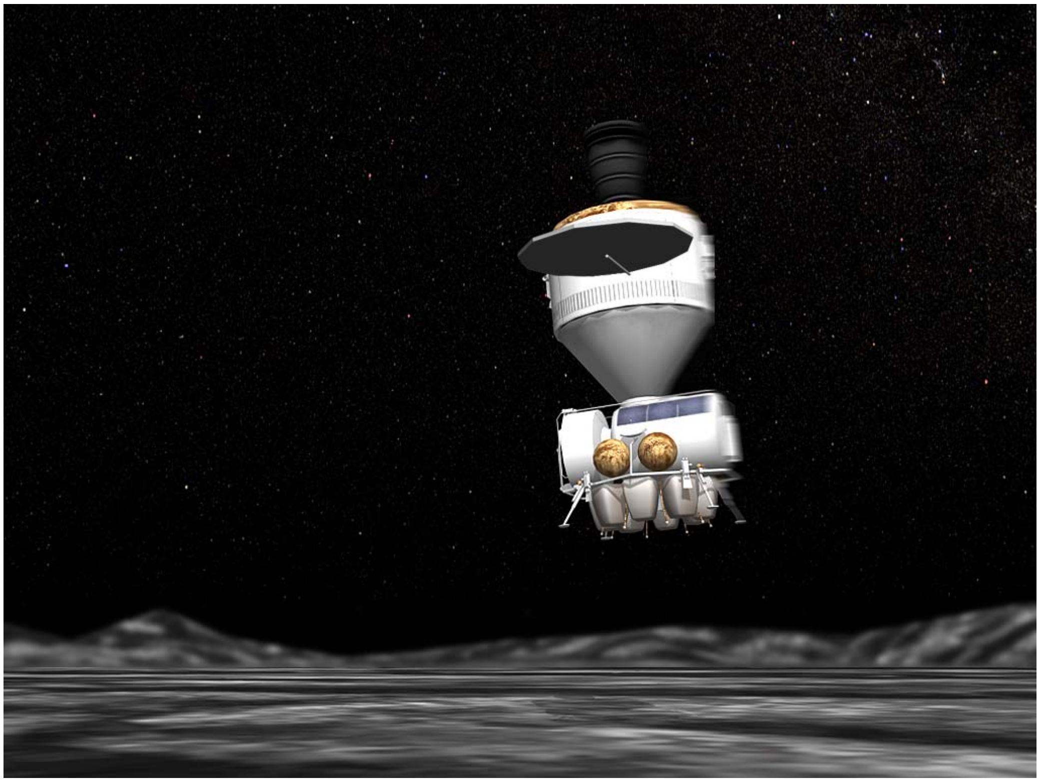

Fig 15: Close sensing of NEO surface

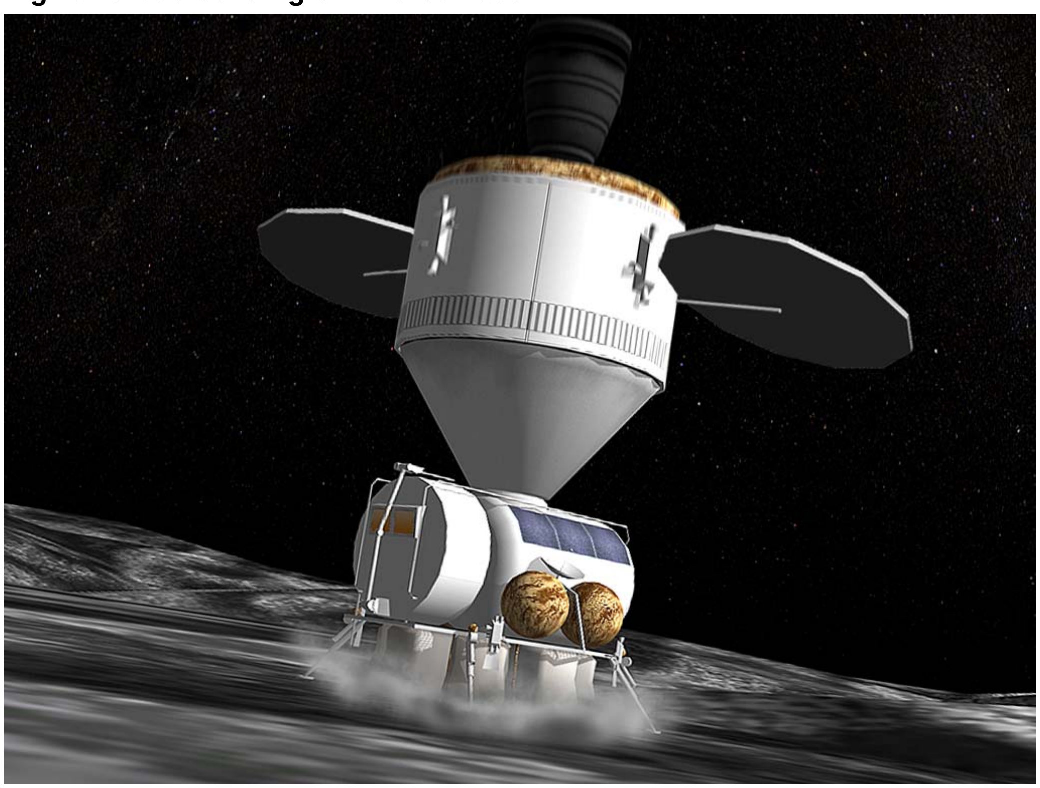

Fig 16: NEO soft berthing attempt with airbags, bearing load sensors

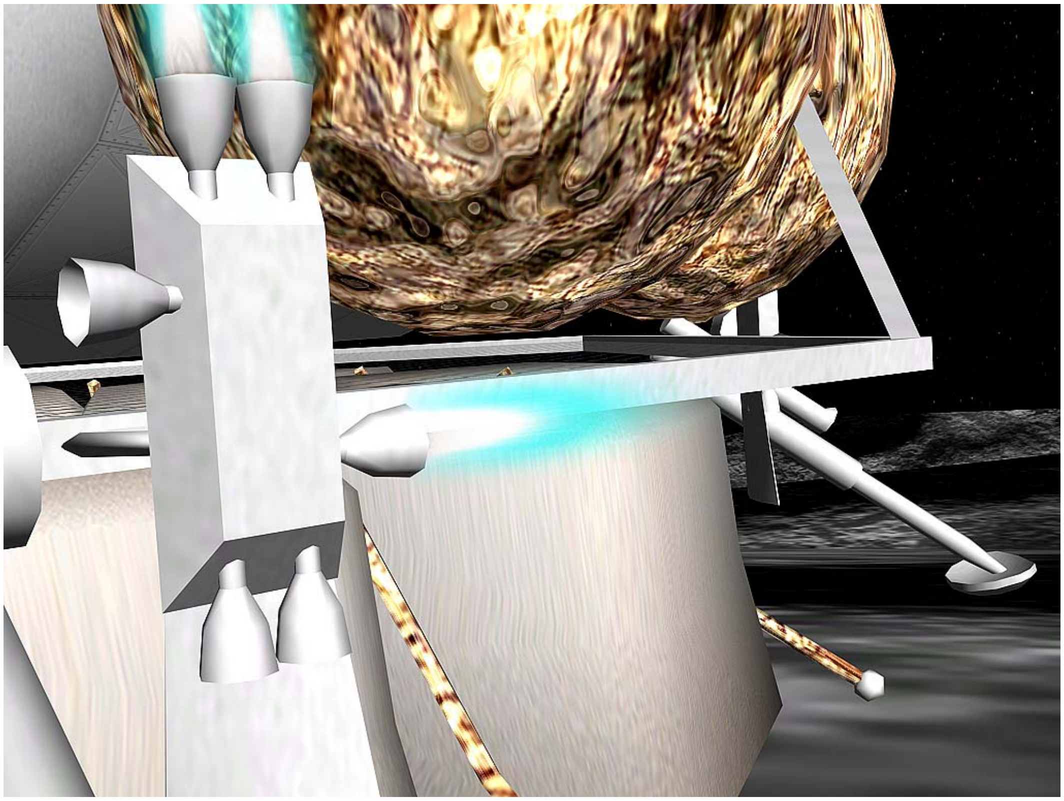

Fig 17: RCS operating on NSAM component, Orion

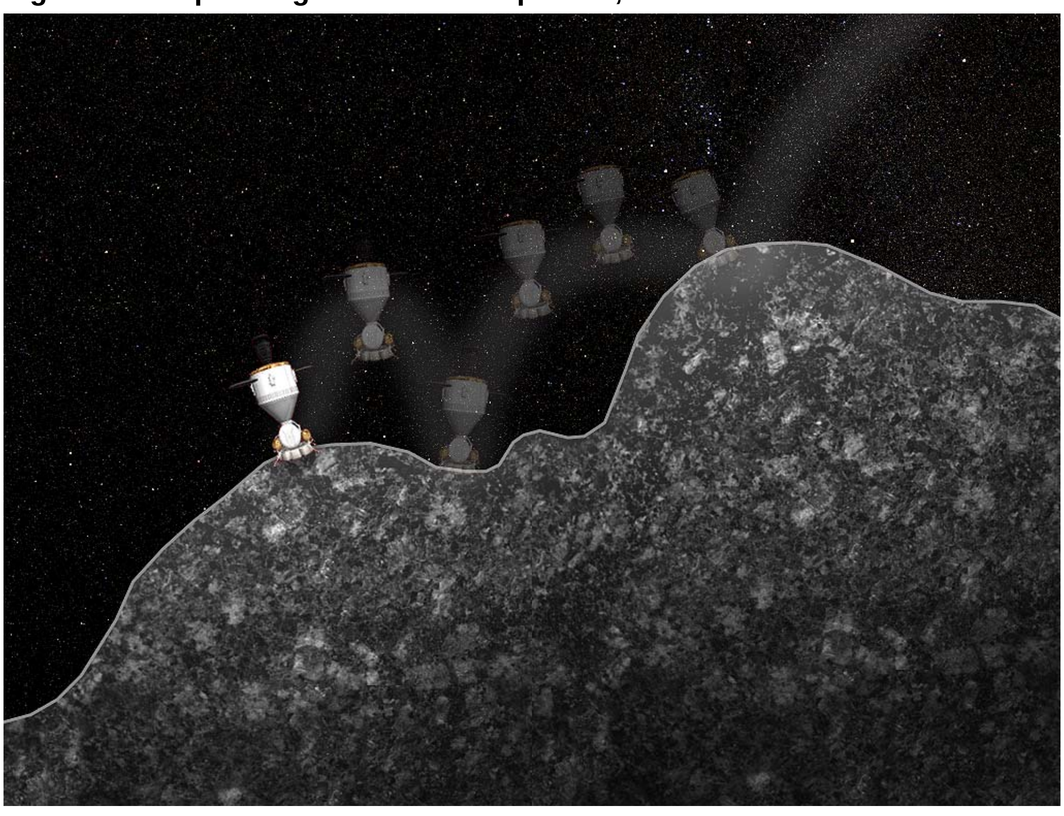

Fig 18: Hopping for secure setdown location and for global access

Step 6: NEO Surface Operations

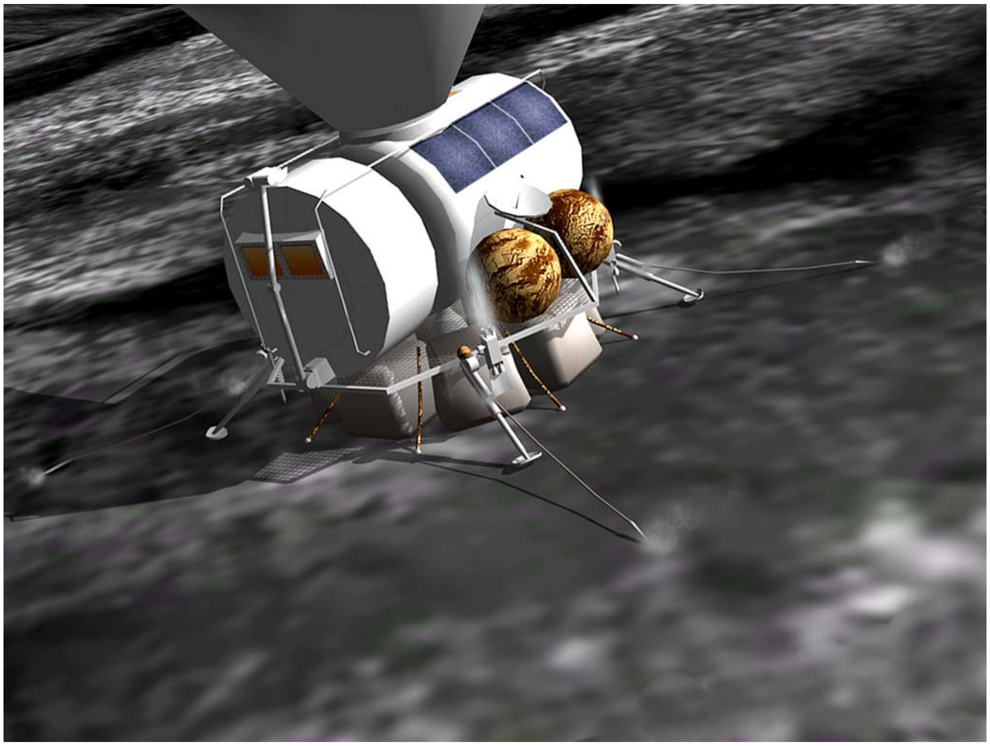

Fig 19: NSAM Secure Tethering using harpoon anchoring

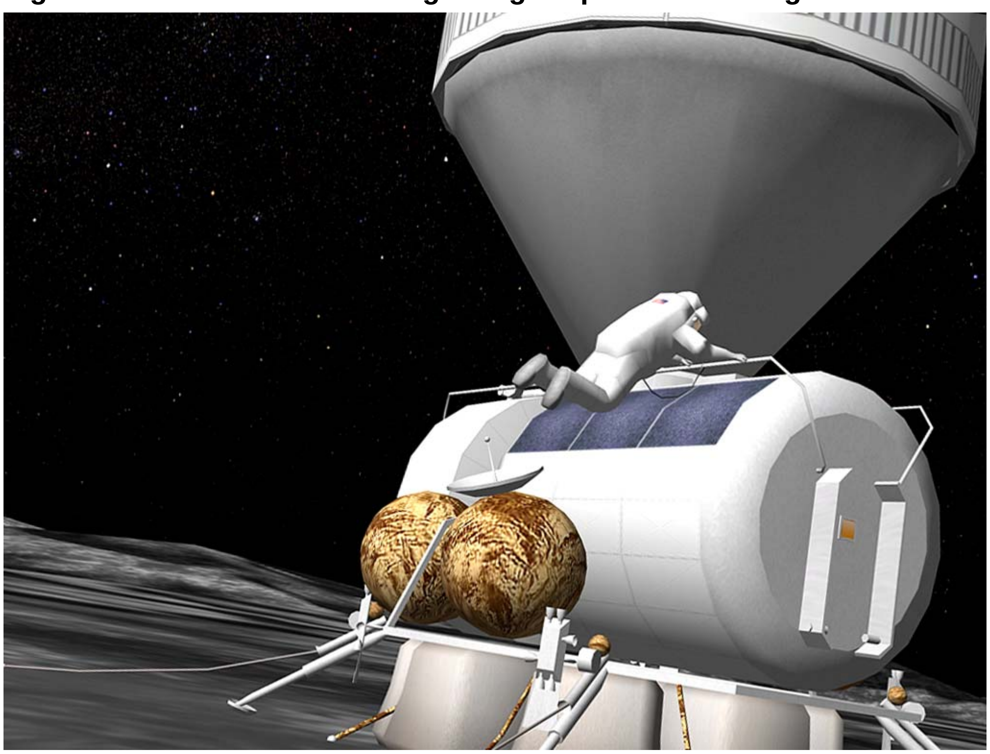

Fig 20: EVA from Orion or NSAM

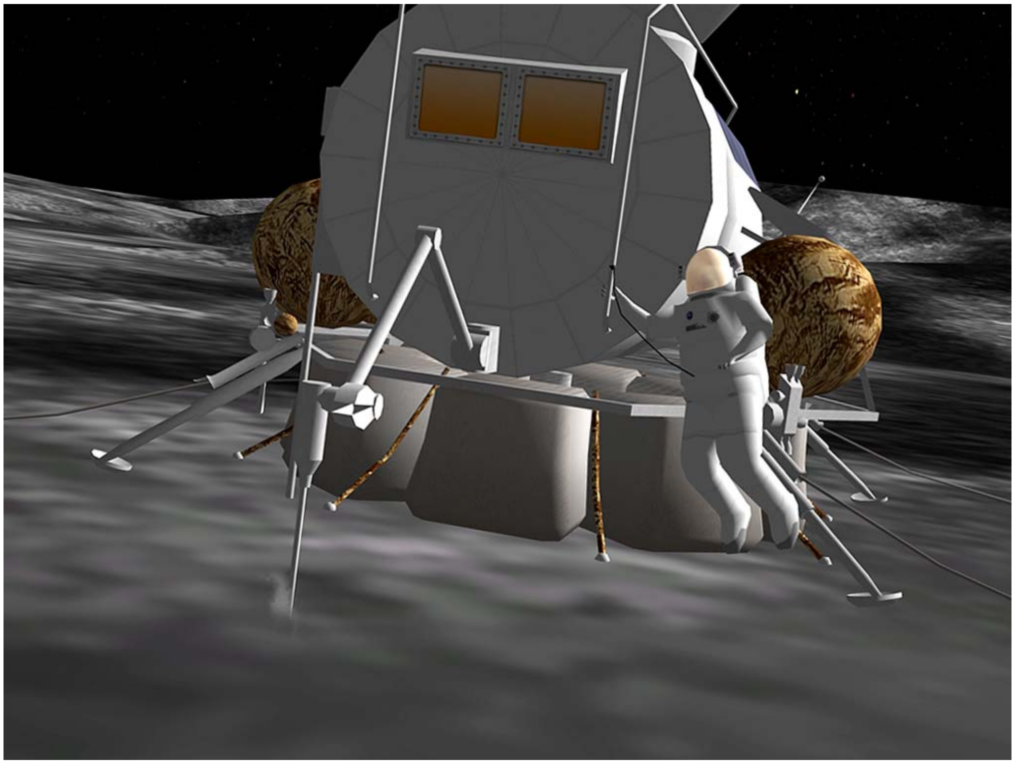
Fig 21: Use of tether to gain access to surface, secure astronaut, teleoperation of drill and sample retrieval

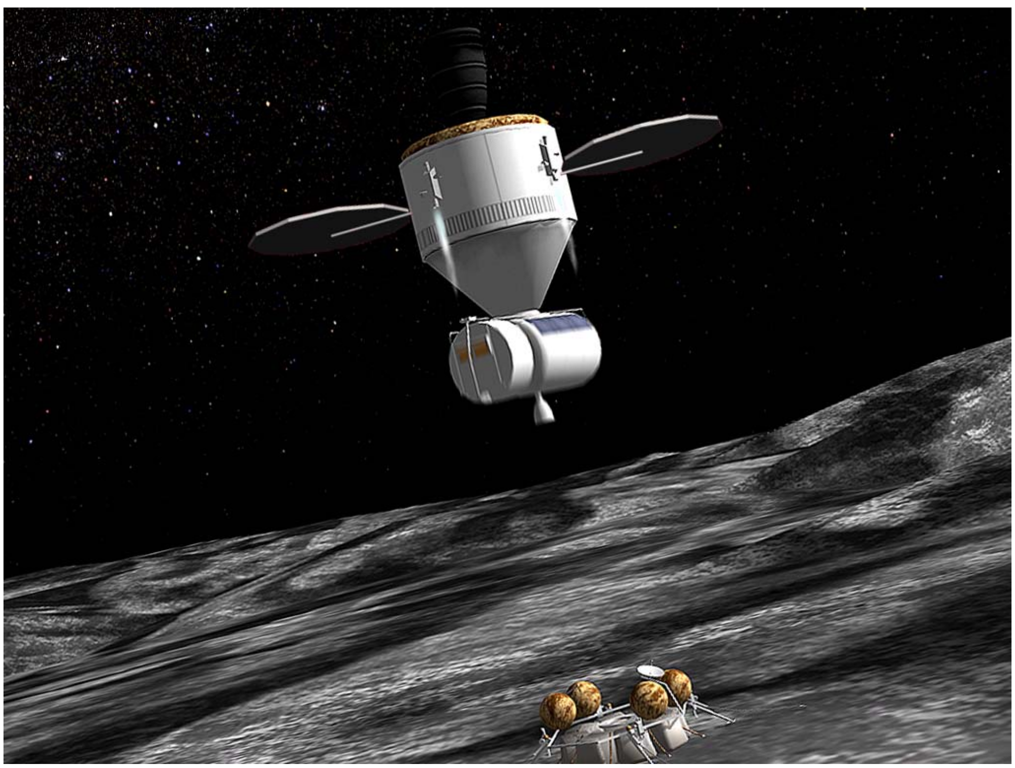
Fig 22: Departure from NEO surface, stay-behind science package with communications, backup power, instrumentation

Step 7: Departure and Earth Return

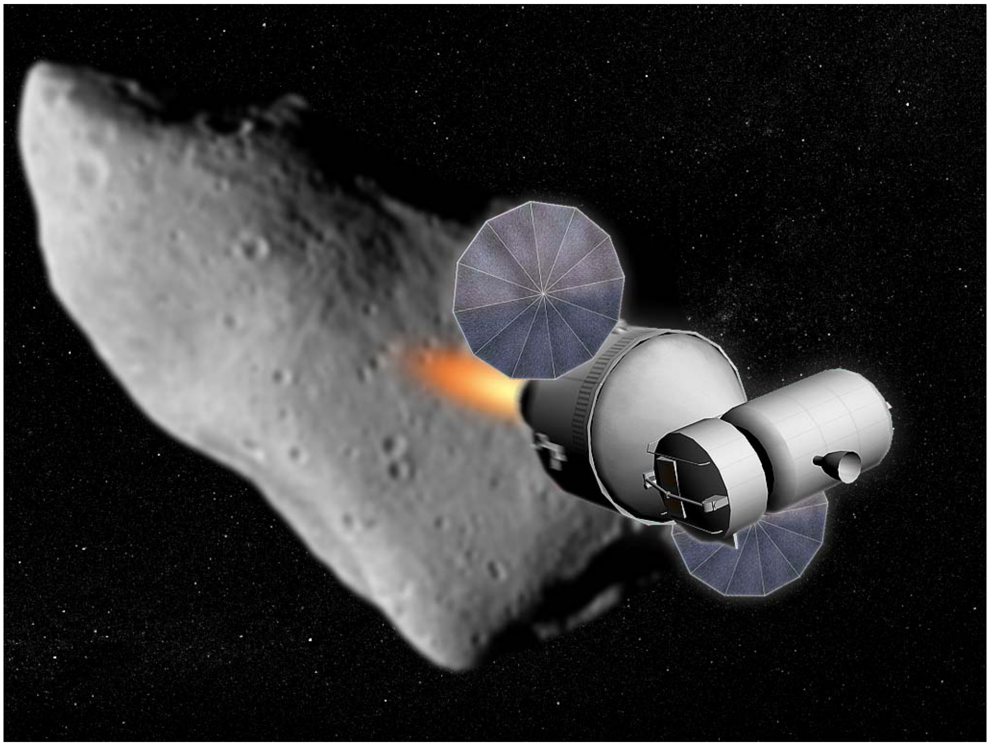

Fig 23: TEI burn

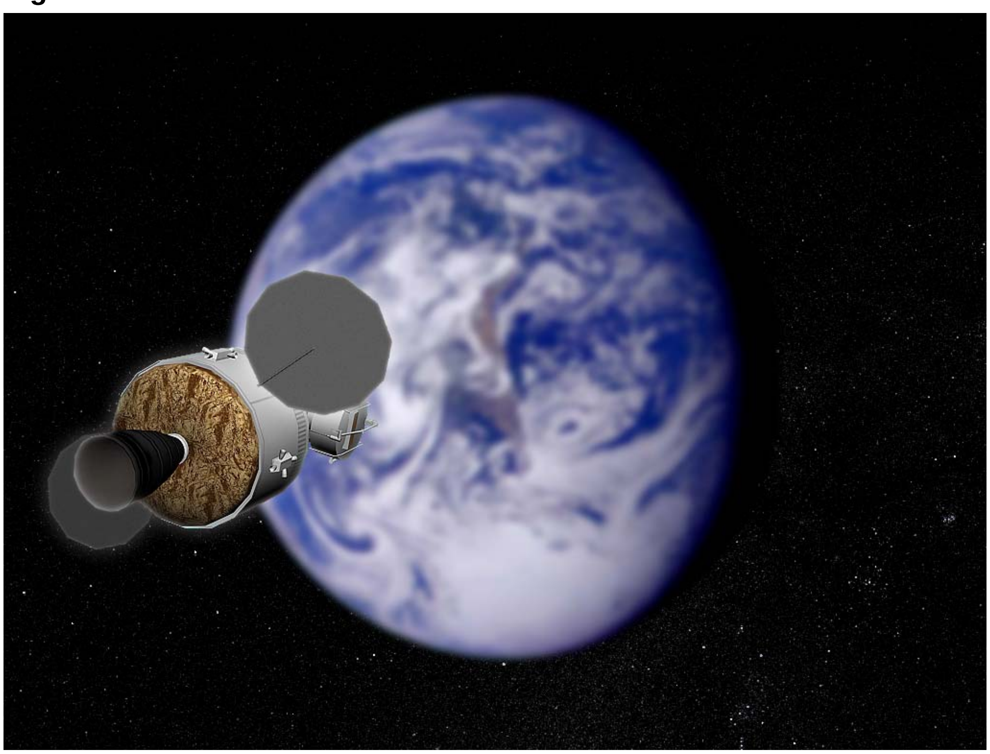

Fig 24: Earth approach

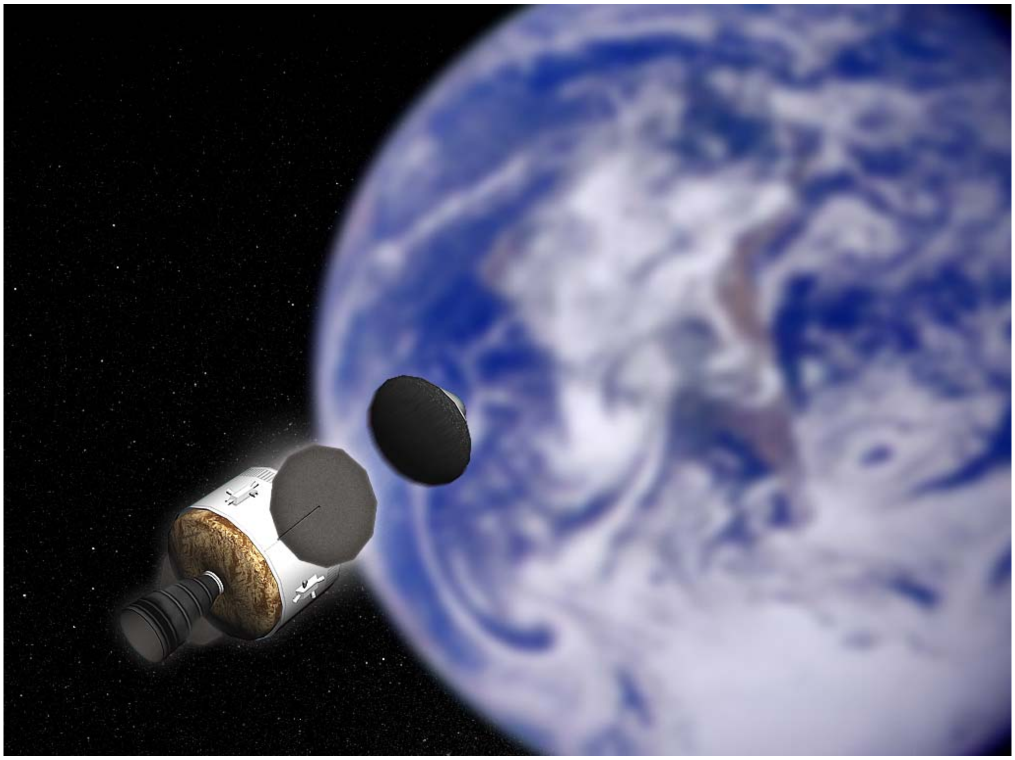

Fig 25: Reentry capsule separation

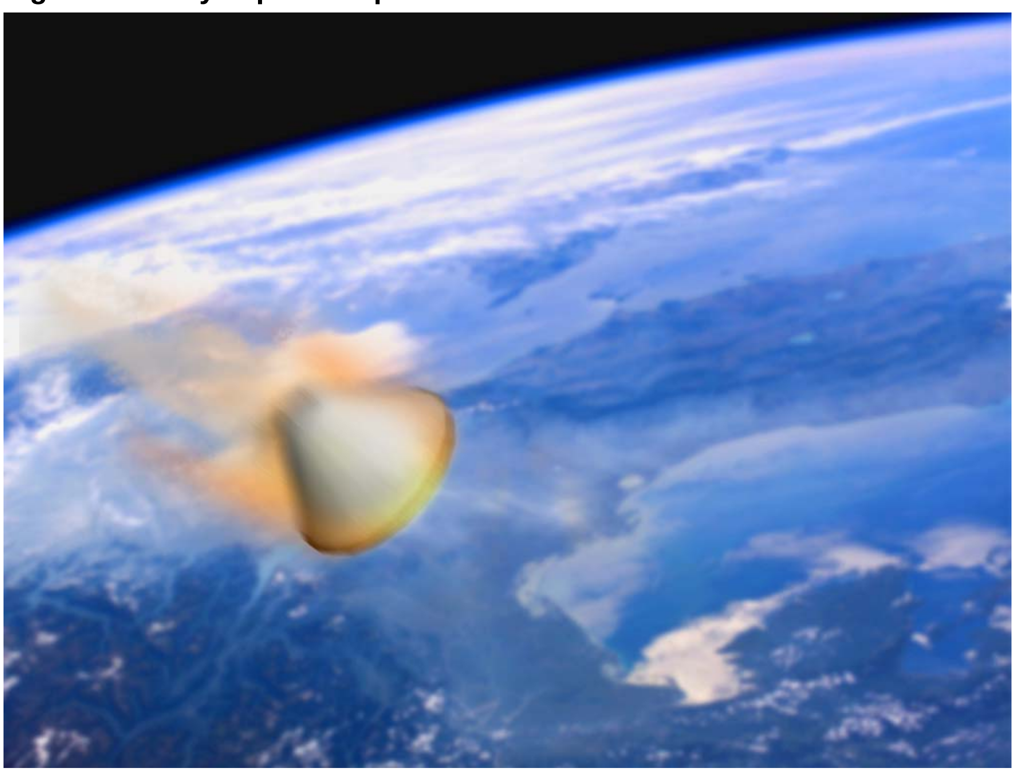

Fig 26: Reentry

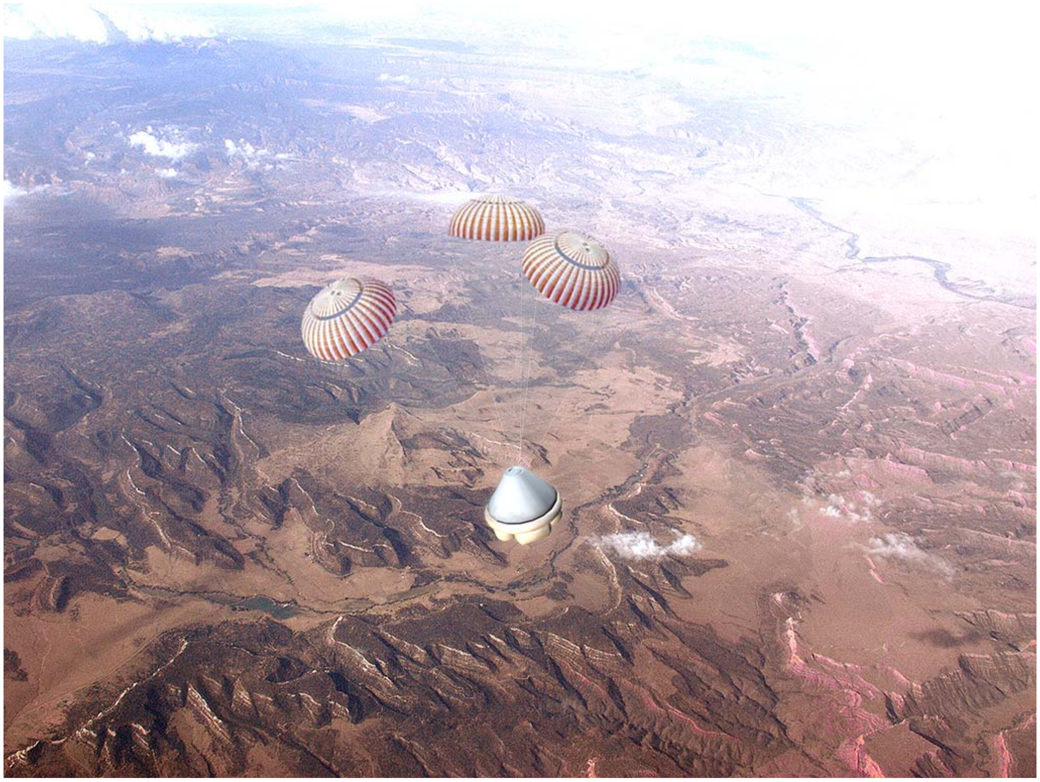

Fig 27: Descent and landing

Detail: Function and Benefits of the NSAM Berthing Design

1. A primary benefit of this design is the enablement of **multiple mission profiles and safe fallback positions** with increasing level of engagement. These include:

- engage NEO target at a station-keeping distance;
- make one or more close approaches for remote sensing;
- attempt one or more “touch, sample and go” surface contacts;
- create a temporary (possibly unstable) holdfast on the surface with more extensive sampling (non EVA);
- secure long term holdfast on surface (with EVAs);
- secure multiple long term holdfasts on surface (with EVAs).

2. **A flexible NEO berthing technique** using multiple modalities and levels of safe fallback is another benefit of the desing. The Airbag + sensor + harpoon anchor tether approach mimics the system used by insects to secure themselves to surfaces in the presence of air movement, analogous to a heavy object trying to grapple a possibly unstable surface in low gravity. Using the airbags the vehicle would be able to make a soft surface impact distributed around a ring of bags. Surface “neotechnical properties” including load bearing strength and surface density could be made instantly by probe sensors mounted on the airbag

ring. Thus, the quality of a likely "seal" could be determined rapidly and at several locations on subsequent hops. When an optimal seal (stable, penetrable surface) is sensed, the harpoon tether system could be activated to attempt to create a fast hold.

In the case of a secure hold on a suitable proportion of the four or more tethers, teleoperating of the tether winches could be engaged to tighten or loosen the tethers. Safe berthing could enable EVA and manual adjustment of the tether or the harpoon end.

In the case of an insecure hold tether retraction could be attempted. Teleoperated retraction, EVA assisted retraction or "harpoon drop" could leave the anchor end in the NEO surface and allow the tether to be rewound. Another hop attempt could be tried. EVA could be engaged to replace a tether harpoon.

In the case of a highly risky tether (falling stack) an emergency abort could be effected by dropping the entire stay-behind base and departing the NEO surface.

3. **A substantial stay-behind science station** is another benefit of this design. The NSAM base, including decking, RCS station keeping fuel tanks, airbag, sensor and instrument ring would be decoupled from the Orion/NSAM habitat module at departure and remain behind secured to the NEO surface. A communications and solar power package (or fuel cell with source) could permit longer term science and communications with earth with enough power to position the dish and track Earth if the NEO is a presumed slow rotator. Any externally deployed science package could be power/data cabled to the station. This station is effectively a NEO version of the Apollo LSEP (an NSEP). Lastly, the mass left behind on the NEO will lower fuel costs for the Trans Earth Injection (TEI).

Secure web location of this visualization

This imagery can be found at the following secure web location:
http://www.digitalspaces.net/projects/landisscenario/album.html

Username: LandisScenario
Password: CH3swaZu

2) DSS Scripting Interface

In this period we delivered the 0.7 release of the Digital Spaces (DSS) Prototyper. The first application using the full Python scripting interface is a commercial application being produced for Xstrata (formerly Falconbridge) of Canada. This is a research project directed by Brad Blair (a mining economist) and Peter Rutherford, senior systems engineer at Xstrata in Canada. The application involves the simulation of a drill jumbo vehicle for the mining manufacturing firm Atlas Copco in Sweden. This application is available for download (on request) and is the first major implementation of the Python scripttng interface. See figures 28-30 below for outputs of the drill jumbo application.

Drill Jumbo Application

Fig 28: Atlas Copco drill jumbo at work in mine

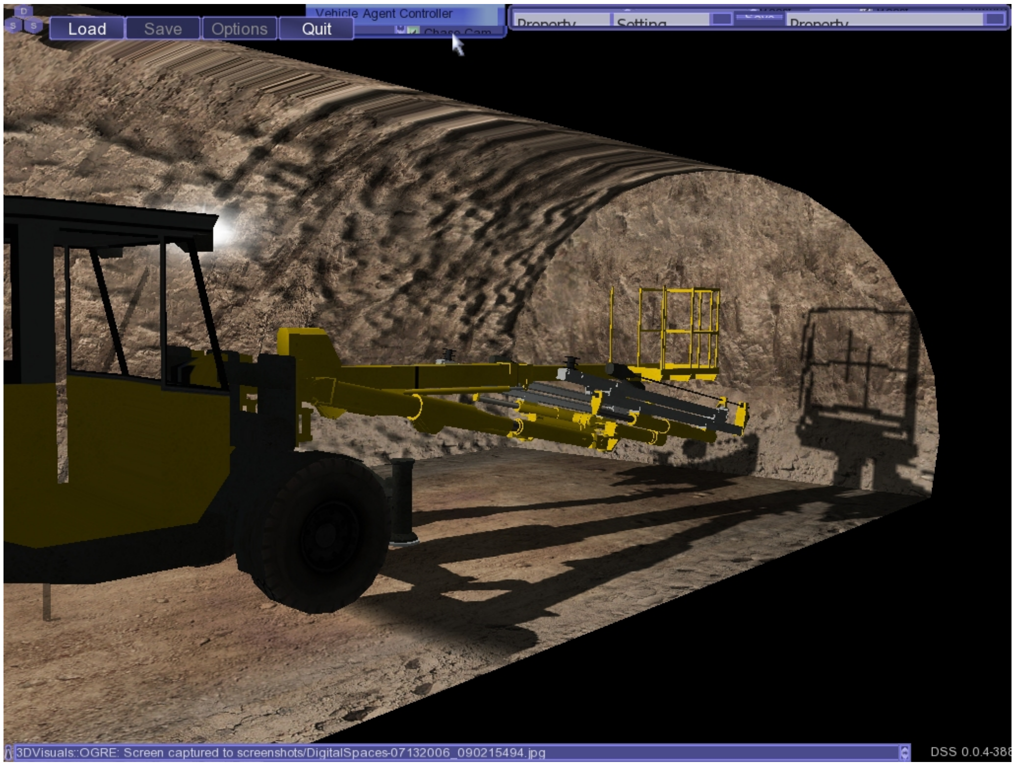

Fig 29: DSS-prototyper Atlas Copco drill jumbo simulation with Python scripting

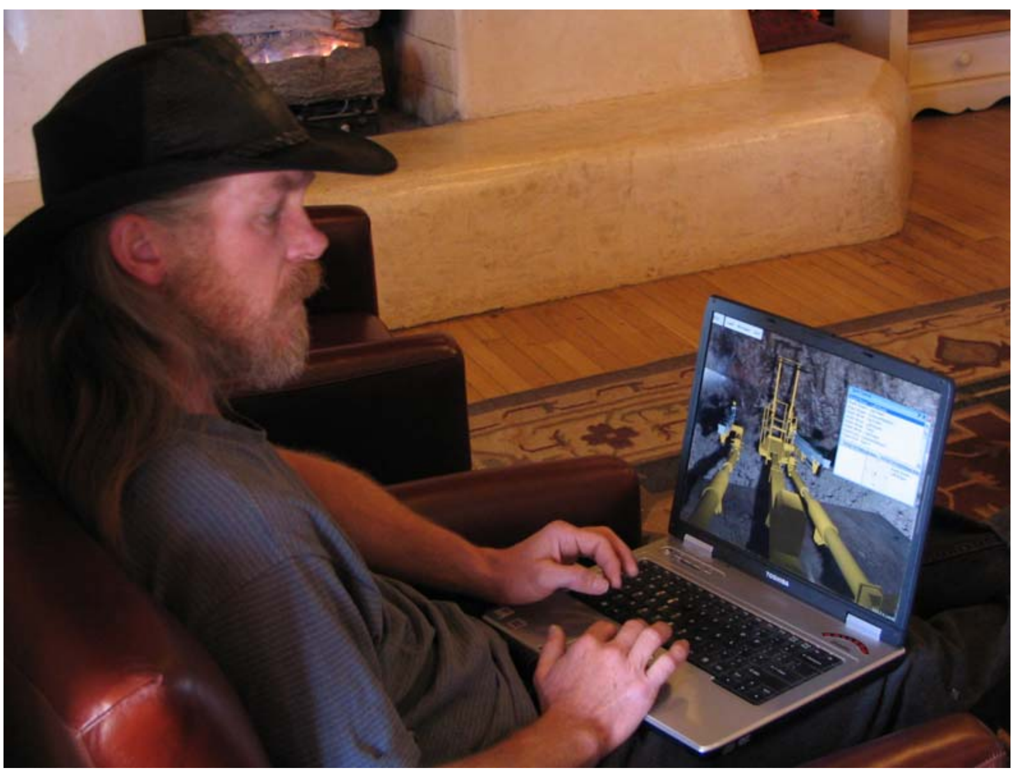

Fig 30: Mining economist Brad Blair developing new scripting interfaces to Drill Jumbo simulation

Drill Jumbo Control Script

The Drill Jumbo Control Script simply allows control of a set of physics rigged joints. The developer is able to specify the joint name, a descriptive name, as well as motor speed and force. The end user is presented with a GUI that allows them to select joints, assign them to the axis of an imaginary joystick, and rotate the joints about their axis. A more detailed report on the implementation of this script is available.

End of report.