Testing of the Orion Optical Navigation Image Processing Algorithms

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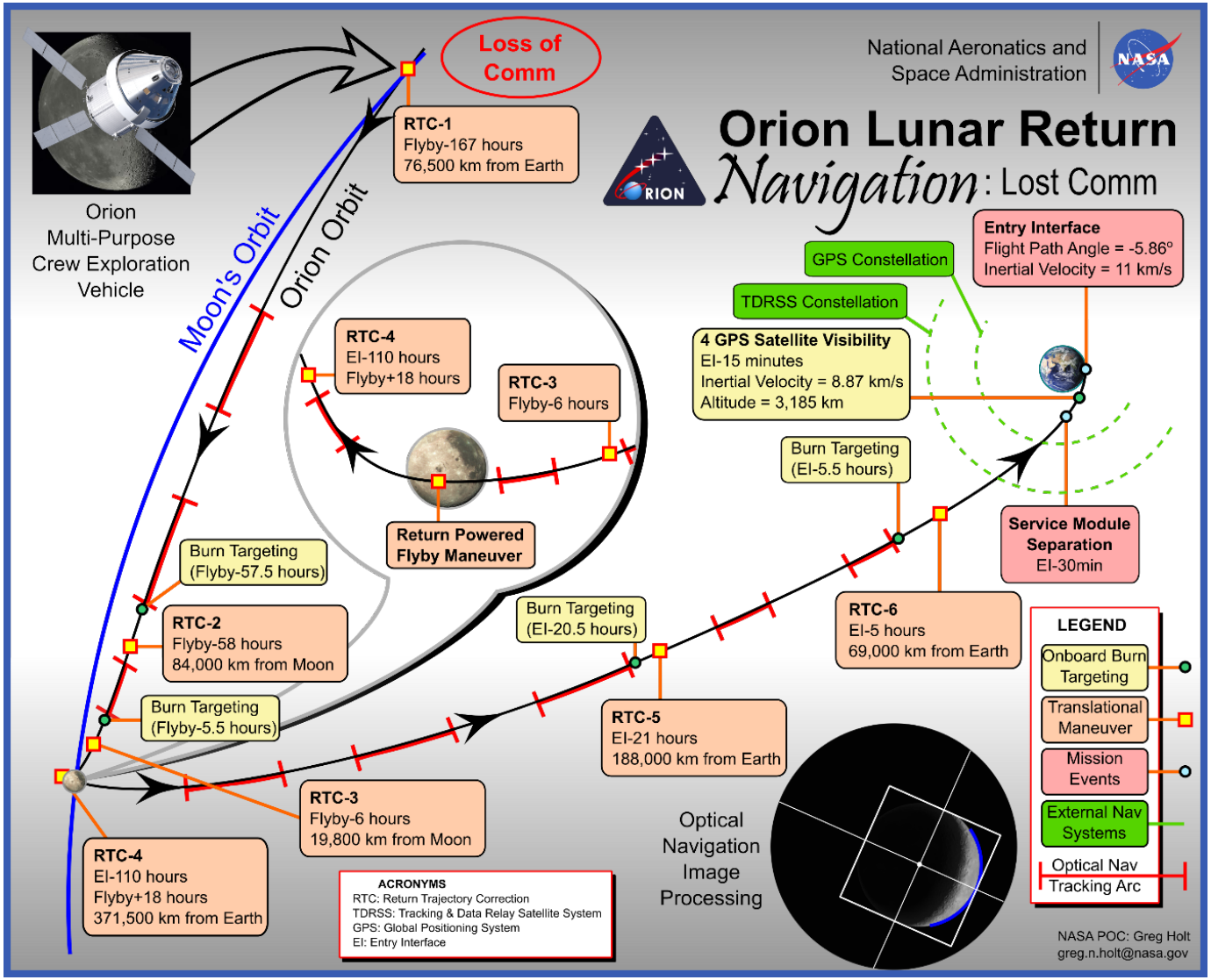
Outline

- The Need
- Optical Navigation Challenges on Orion

The Need

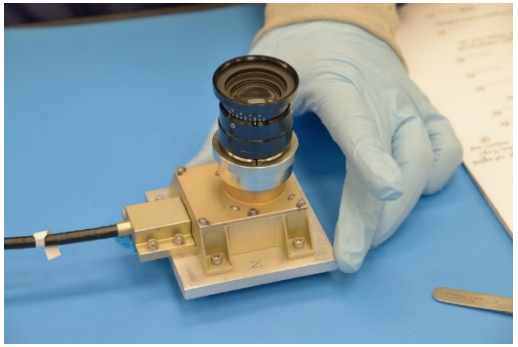
- **Human exploration missions need to be able to operate independent of the ground in case of Loss-of-Communications with the ground**
  - Need to be able to return the crew safely to earth in the case of loss of comm
- **This means (among other things) that the vehicle needs to perform navigation functions independent of the ground (tracking)**
  - Navigation needs to be performed on-board the vehicle
- **This has to do with both position/velocity as well as attitude**
- **Vehicles need to operate both in the vicinity and away from a planetary body**
- **Future vehicles will place increasing demands on the volume of data being transmitted**
  - HD imagery
  - Navigation passes constrain the amount of data transmitted during navigation passes
  - Depending on the accuracy, navigation passes demand a fair amount of tracking resources

What happens on Orion if we lose comm?

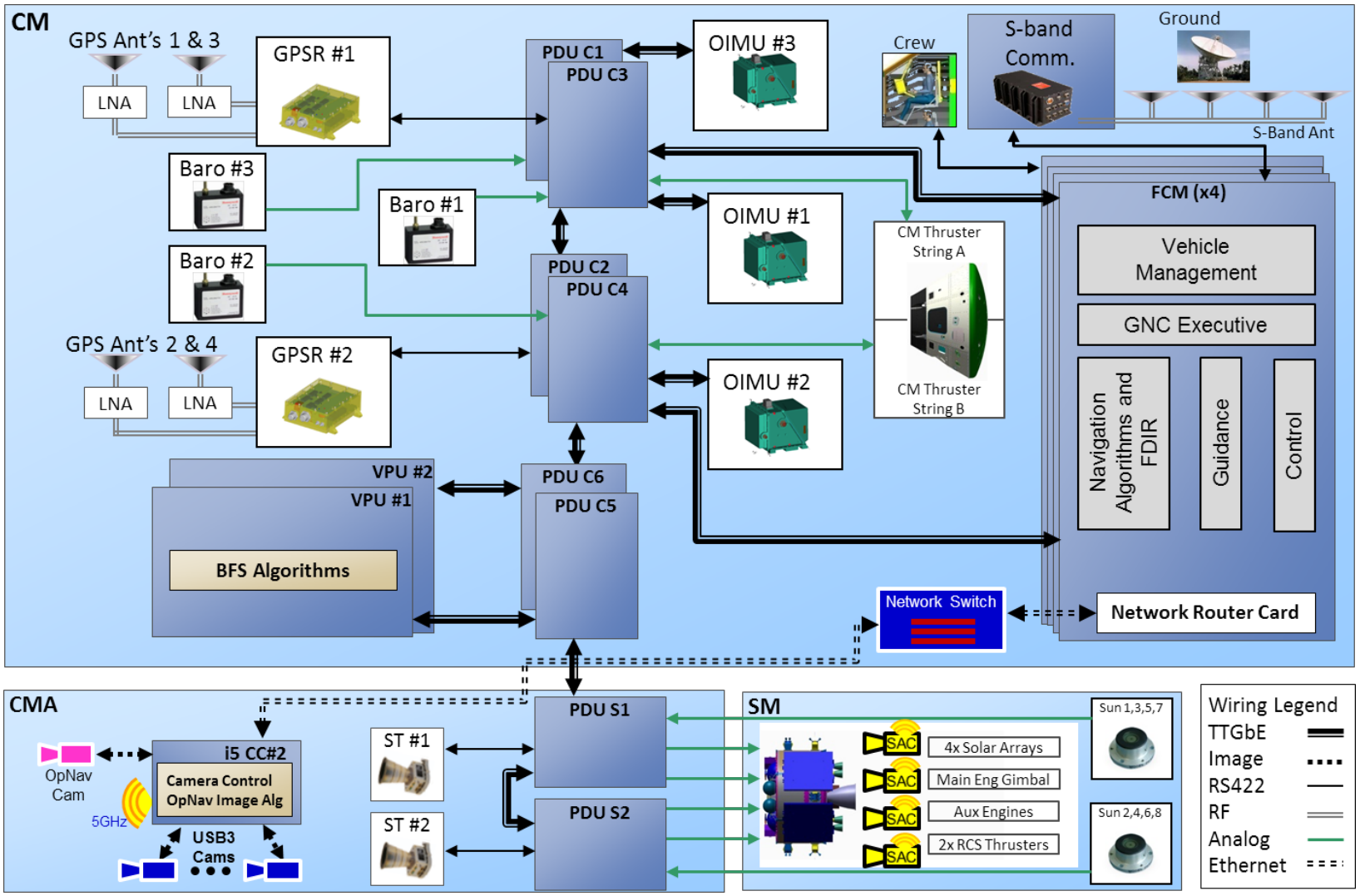


Challenges for Optical Navigation on Orion

- **For EM-1 Orion will be using Earth and Moon images to perform navigation**
  - Resolved body
  - Illuminated limb tracking
- **The optical navigation camera is a monochromatic version of the situational awareness cameras used on Orion**
  - Custom lens (35.1 mm focal distance)
  - Mounted on a optical base on the Crew Module Adaptor (CMA)
    - Away from the IMUs
- **Earth navigation challenges**
  - Atmosphere effects
    - No good (usable) models
  - Paucity of space-based images available for testing
- **Moon navigation challenges**
  - Terrain variation



The Orion Autonomous Navigation Architecture



The Measurements and Measurement Processing

- **The image processing software produces a range to the body and the horizontal and vertical angle to the center of the body**
  - Modeled as a triaxial ellipsoid
- **The associated attitude information is obtained by one of the Star Trackers**
  - The inter-lock angle is estimated as part of calibration
- **The image is time-tagged by the i5 computer at the time of reception of the image from the camera**
- **The resulting measurements are sent to the Cislunar EKF on the Orion VMC (Vehicle Management Computer)**

Overview of OpNav Functionality

The Orion OpNav System has two modes:

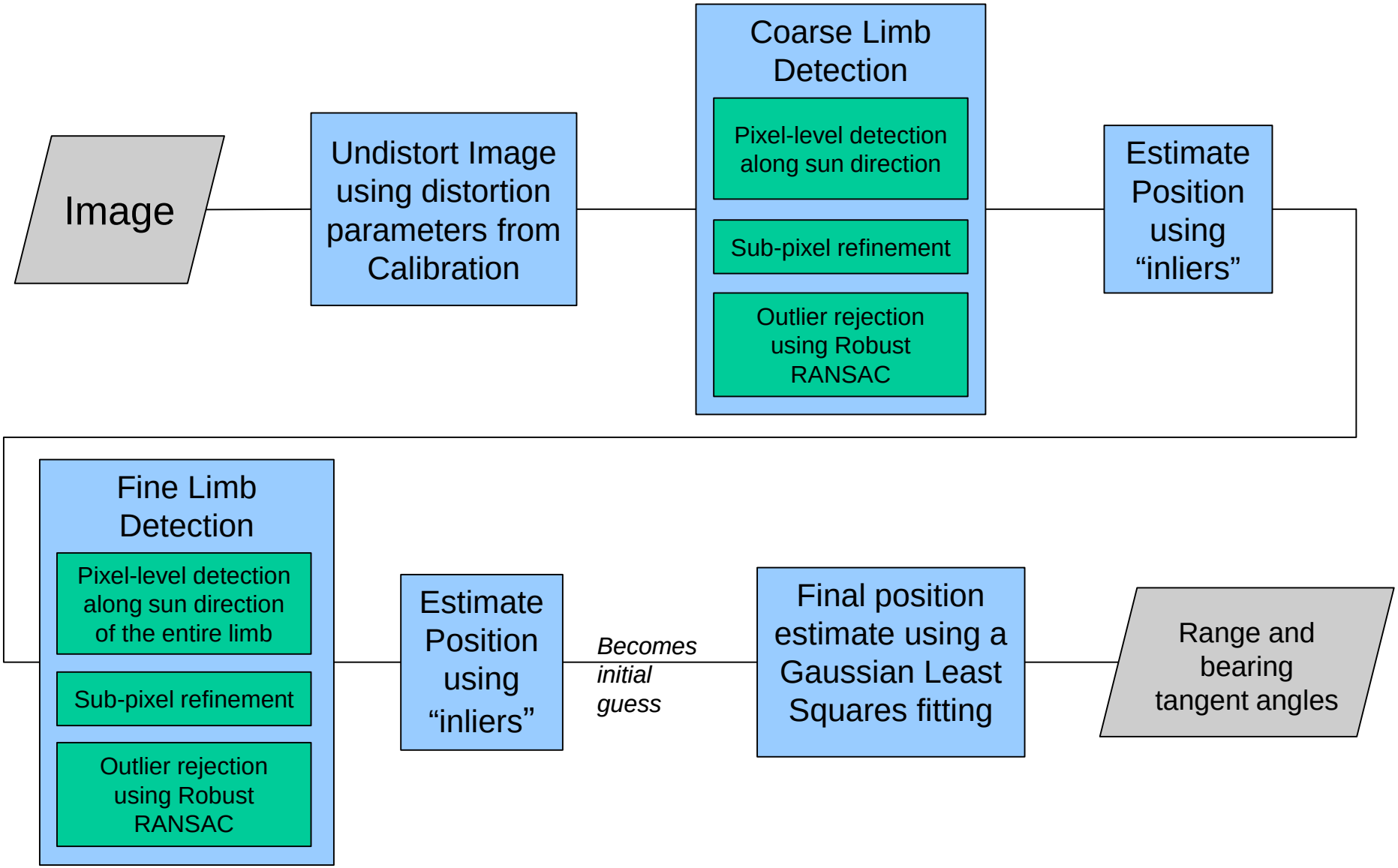
Calibration mode and ***Image Processing*** mode

Calibration modes uses images of the stars to calculate the camera intrinsic parameters, the distortion coefficients, and the Star Tracker to camera interlock angle.

- Camera intrinsic parameters and distortion coefficients are necessary to be able to relate image pixel coordinates to real 3-dimentional coordinates.
- Calibration is done in-flight to characterize any shifts due to launch vibrations or thermal strain.

Image Processing mode takes images of the Earth or the Moon and calculates the range and bearing tangent angles from the camera to the target body.

Image Processing Algorithm



Testing of the Image Processing Algorithm

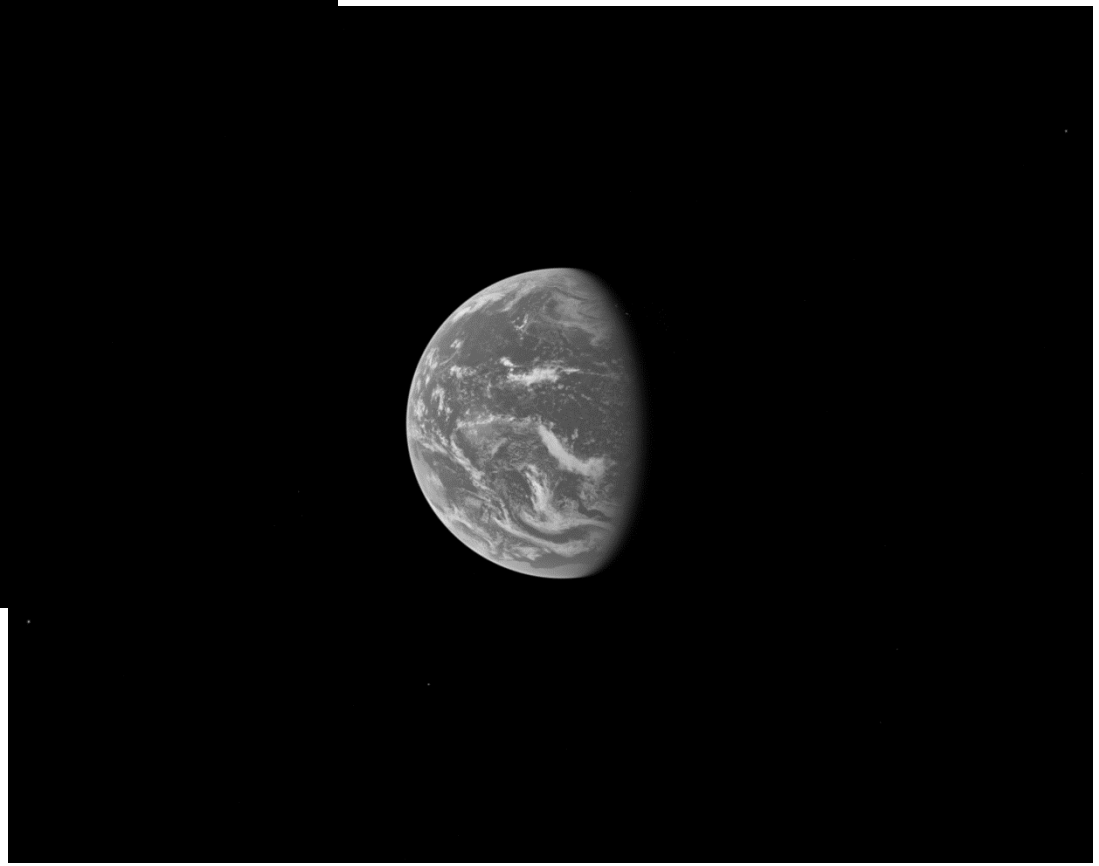
Testing of the Image Processing Algorithm was split into three sets:

- **Verification Images**
  - A nominal set of test images that represent the real conditions of the Orion EM-1 trajectory were used as the verification images.
  - The images were synthetically created using an in-house graphics program called EDGE. EDGE is sophisticated enough to be able to simulate things like the camera intrinsic characteristics, lens distortion, lunar terrain, and the Earth's atmosphere.
- **Off-nominal images**
  - Off-nominal images were created using the verification images as a base and modifying them for different scenarios. For example, over-exposure, solar panels in the field of view, radiation damage, etc.
- **Live-sky images**
  - Real images of the moon taken with the Orion OpNav camera mounted next to a star tracker.

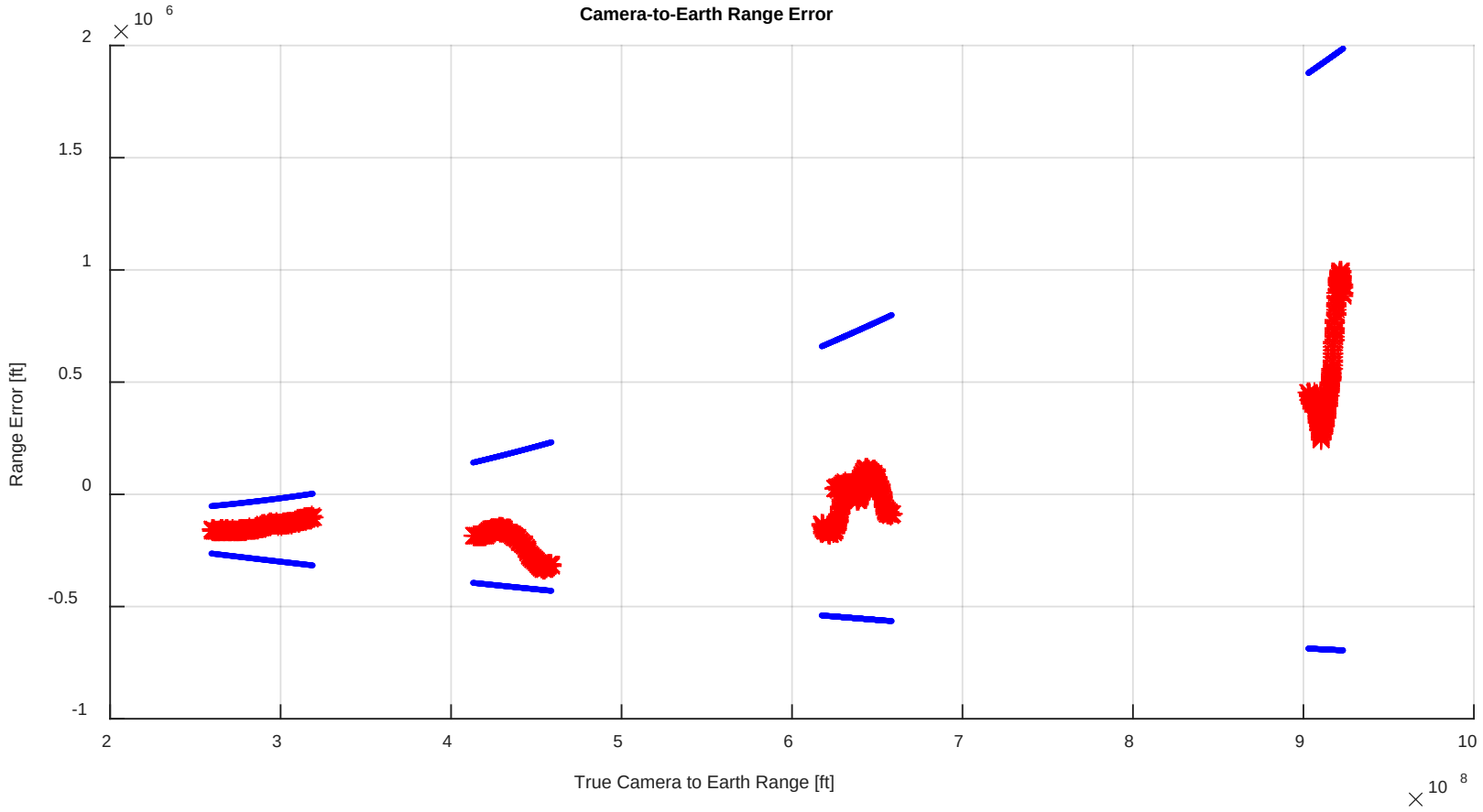
Example Verification Images

Moon Image

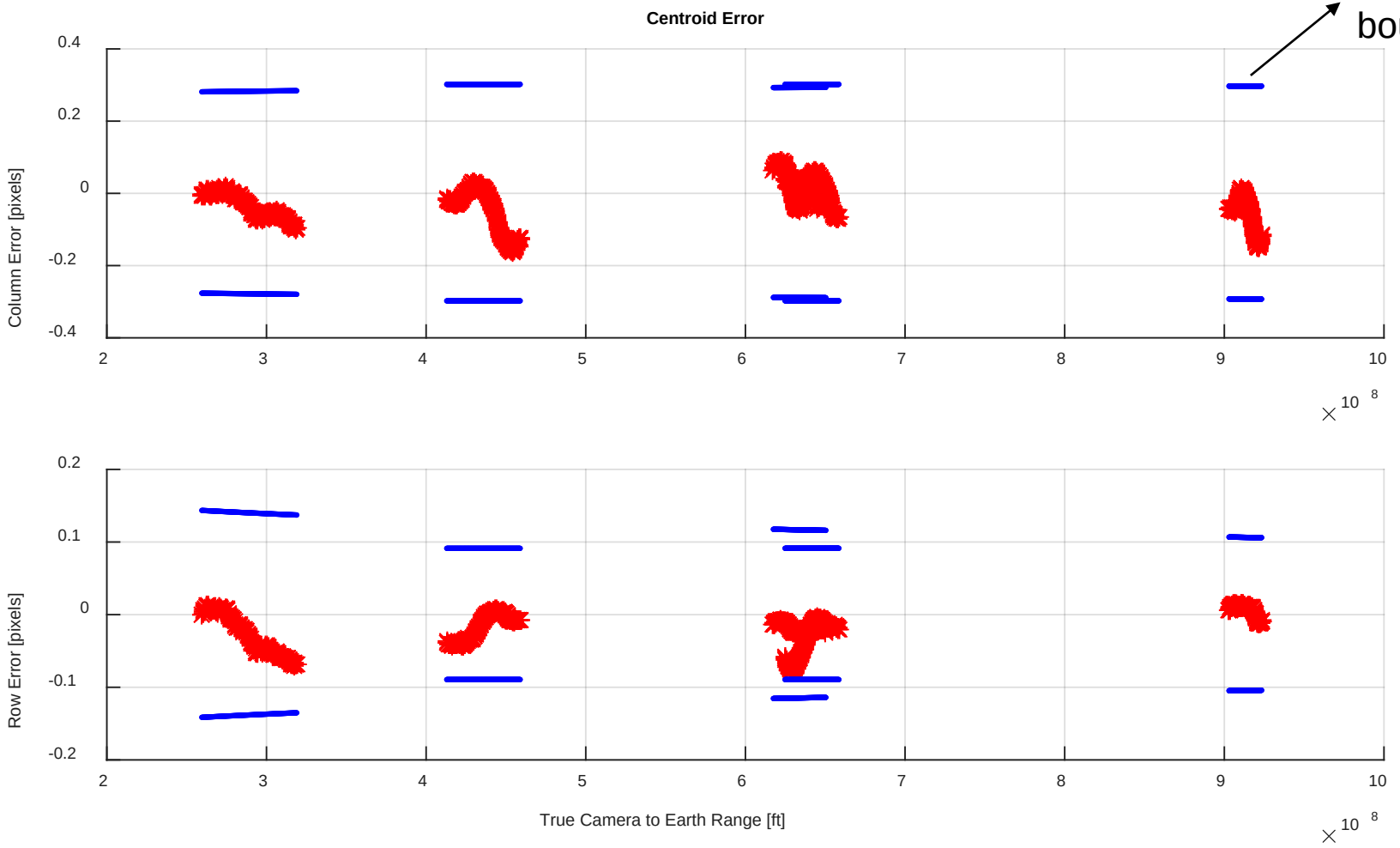
Earth Image



Earth Results



Earth Results



Future Development

- **The image processing and calibration software has been completed and delivered to LM for HWIL testing**
  - All the required artifacts have been developed and delivered and the software is under strict CM
  - Further testing on corner cases is being performed
- **In the coming months the software will be tested in the LM Integrated Test Laboratory stimulated by synthetic imagery displayed on an 8K display**
- **This will be used for an end-to-end test of the entire optical navigation system**