Jet Propulsion Laboratory
California Institute of Technology

The Mars 2020 Lander Vision System

IPPW 2016

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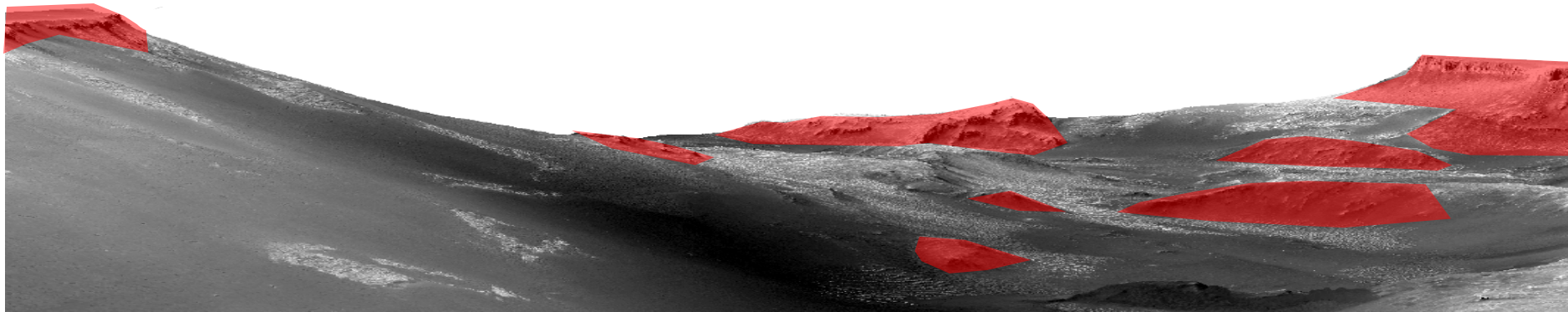
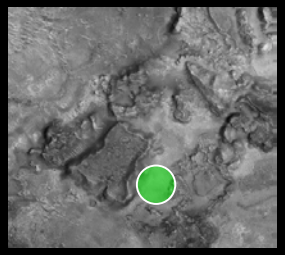
June 14, 2016

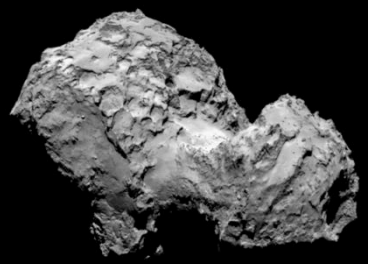


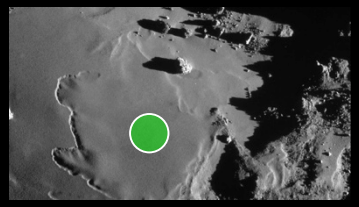
Mars SMD/HEOMD



TRN required to access best science sites and land near pre-deployed assets

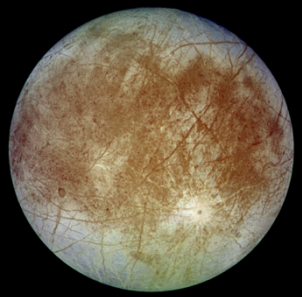
Comets SMD

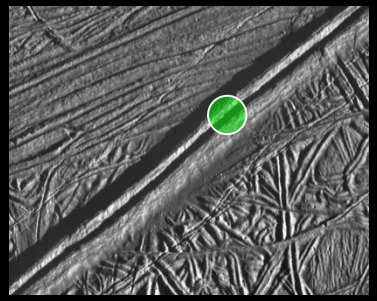




TRN required to safely acquire a sample

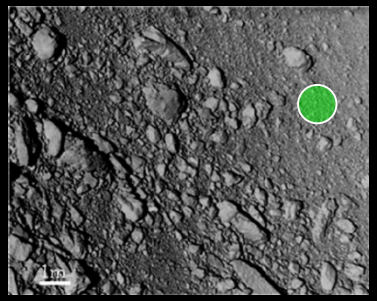
Europa SMD





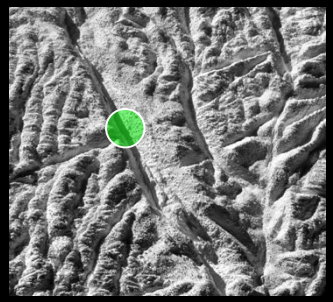
TRN required to land safely on science site

Asteroids HEOMD



TRN required to pick up boulder

Enceladus SMD



TRN required to land near water plumes

The Moon HEOMD

TRN required to access permanently lit terrain

Map Relative Localization (MRL)

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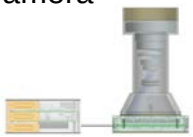
Inputs

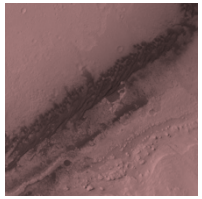
Initial State

```
pos_h: ±3.2km
alt:   ±150m
vel:   ±1.5 m/s
att:   ±0.5˚
```

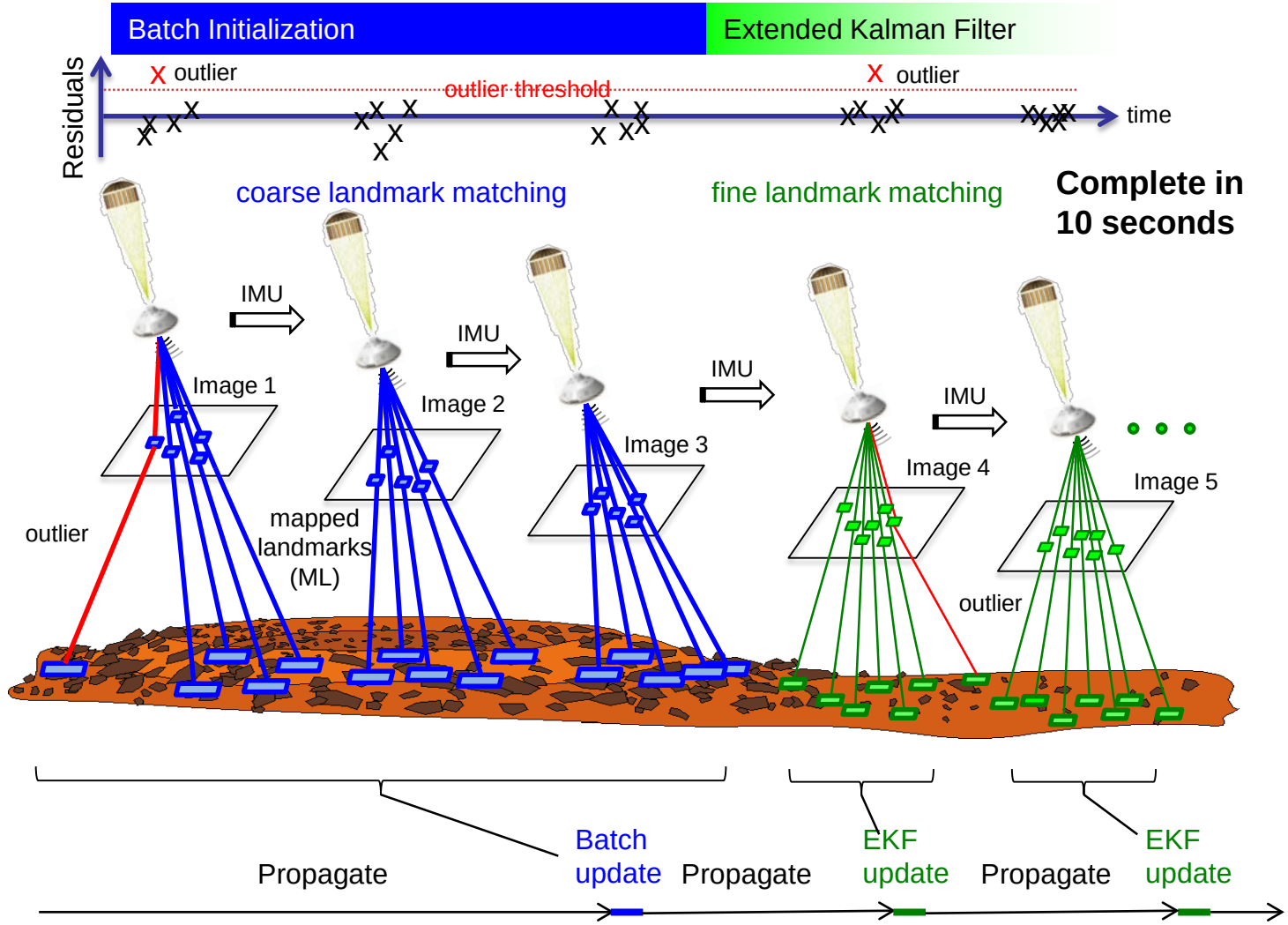
Camera



Map



IMU



Remove Initial Position Error (3km 3-σ)

Final Position Accuracy (40m 3-σ @ 2km)

Flight Vision Compute Element

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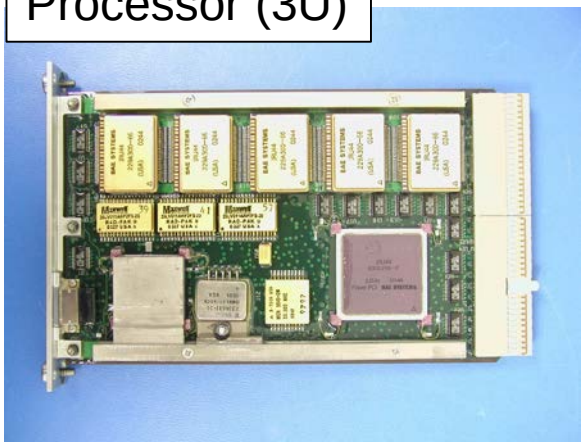
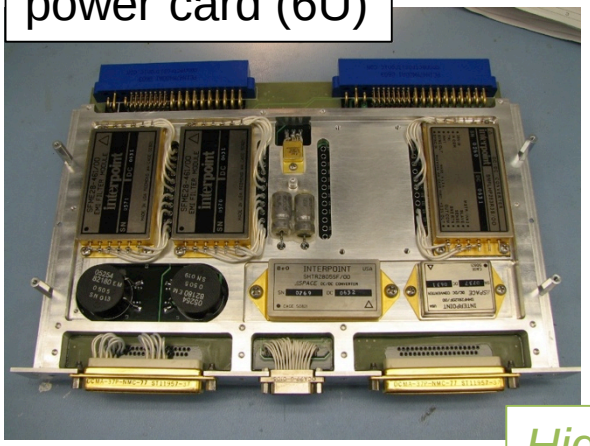
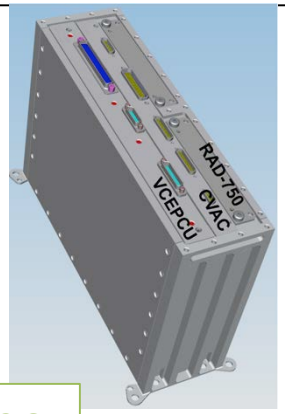
Flight RAD750 Processor (3U)



Flight CEPCU1 power card (6U)

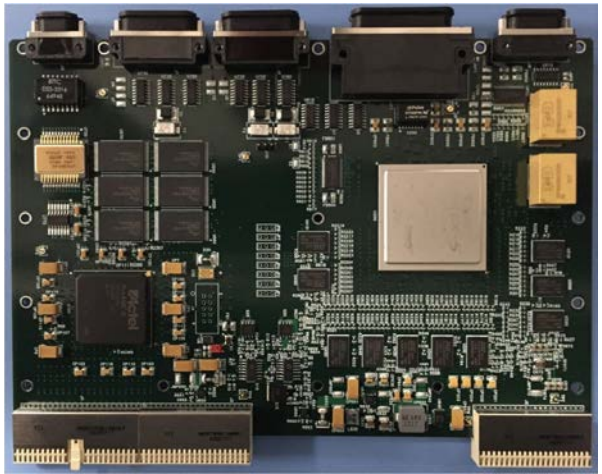


Standard chassis and backplane



High Heritage

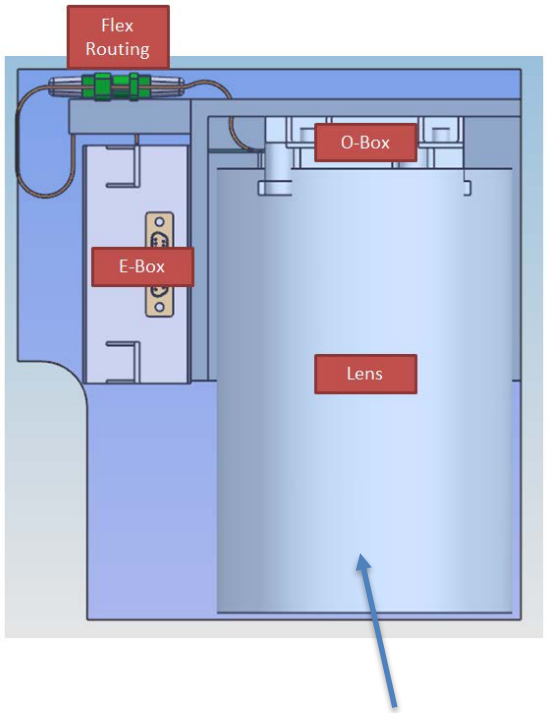
New Computer Vision Accelerator Card (CVAC) (6U)



The Vision Compute Element (VCE) is a 3 slot 6U processor with a RAD750 general purpose processor, a power conditioning card (CEPCU1) and a new Virtex5 enabled Computer Vision Accelerator Card (CVAC).

LVS Camera (LCAM)

- Mass: ~1000 g
- Volume: ~150 mm x ~100 mm x ~100 mm (HxWxD)
  Power: ~4W idle, ~ 8W average, ~11W peak
- Image format: 1024x1024 pixels, 8-bits / pixel
- Spectral range: 480 nm to 720 nm, monochrome
- Field-of-View: 90°x90°, f-tan-theta projection
- Nominal exposure time: ~400µs, global shutter
- Nominal frame rate: 1Hz

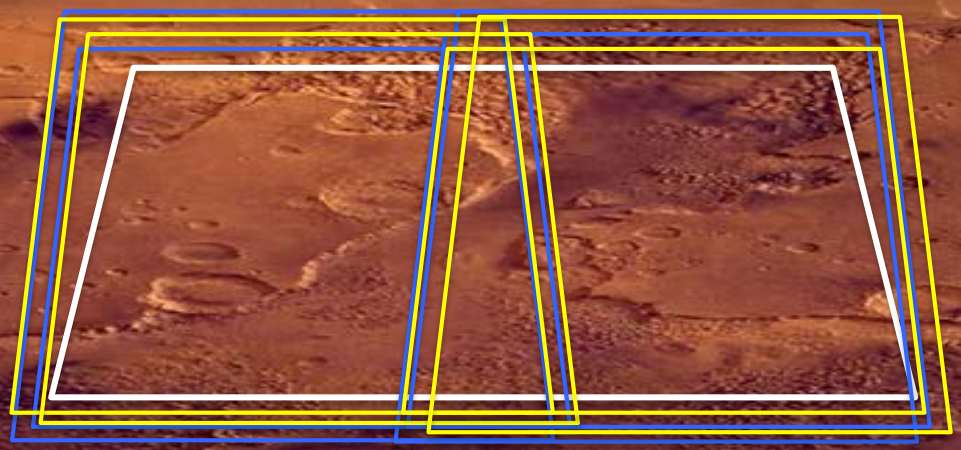


Notional Lens NTE Volume

MRO CTX imaging is used to generate the LVS map

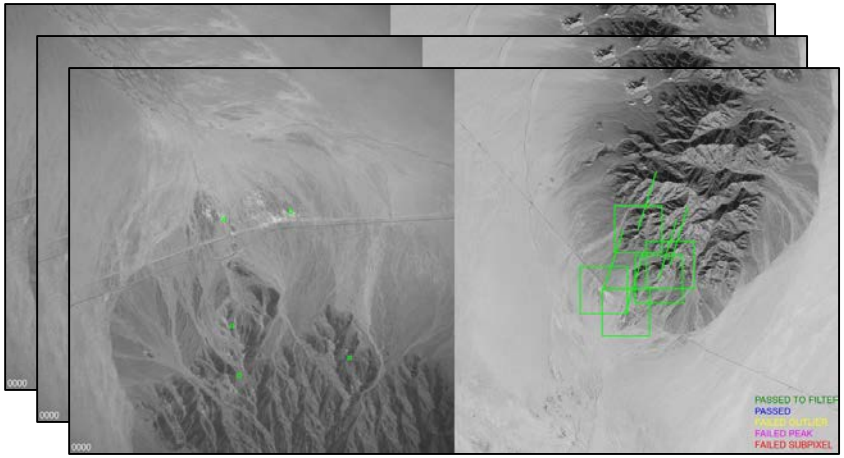
- CTX images are 6m/pixel and about 30km across
- MRO images the landing site around the time of landing (telecom constraint)
- stereo pairs are needed for elevation map generation while one of the stereo images is used for the appearance map

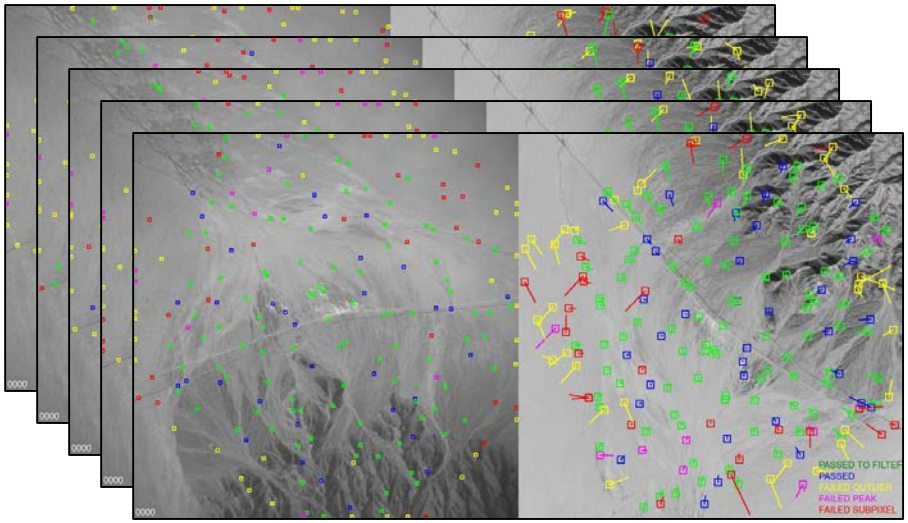
- 2 stereo pairs are needed to cover the map area
- an additional 2 stereo pairs will be used for V&V of the map
- these CTX images are being collected as part of M2020 landing site assessment



LVS elevation and appearance map

MRL Processing Phases





Receiving Spacecraft State

Spacecraft Initialization State (position error < 3.2 km)

altitude < 3700m

Coarse Match

LVS State Estimate (position error < 200m at 4.5s)

3 images processed

Fine Match

LVS State Estimate and Validity (position error < 54m at 6s) (position error < 40m at 10s)

altitude < 2km or BSS

VCEFSWE and MRL Algorithms Data Flow

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California Institute of Technology

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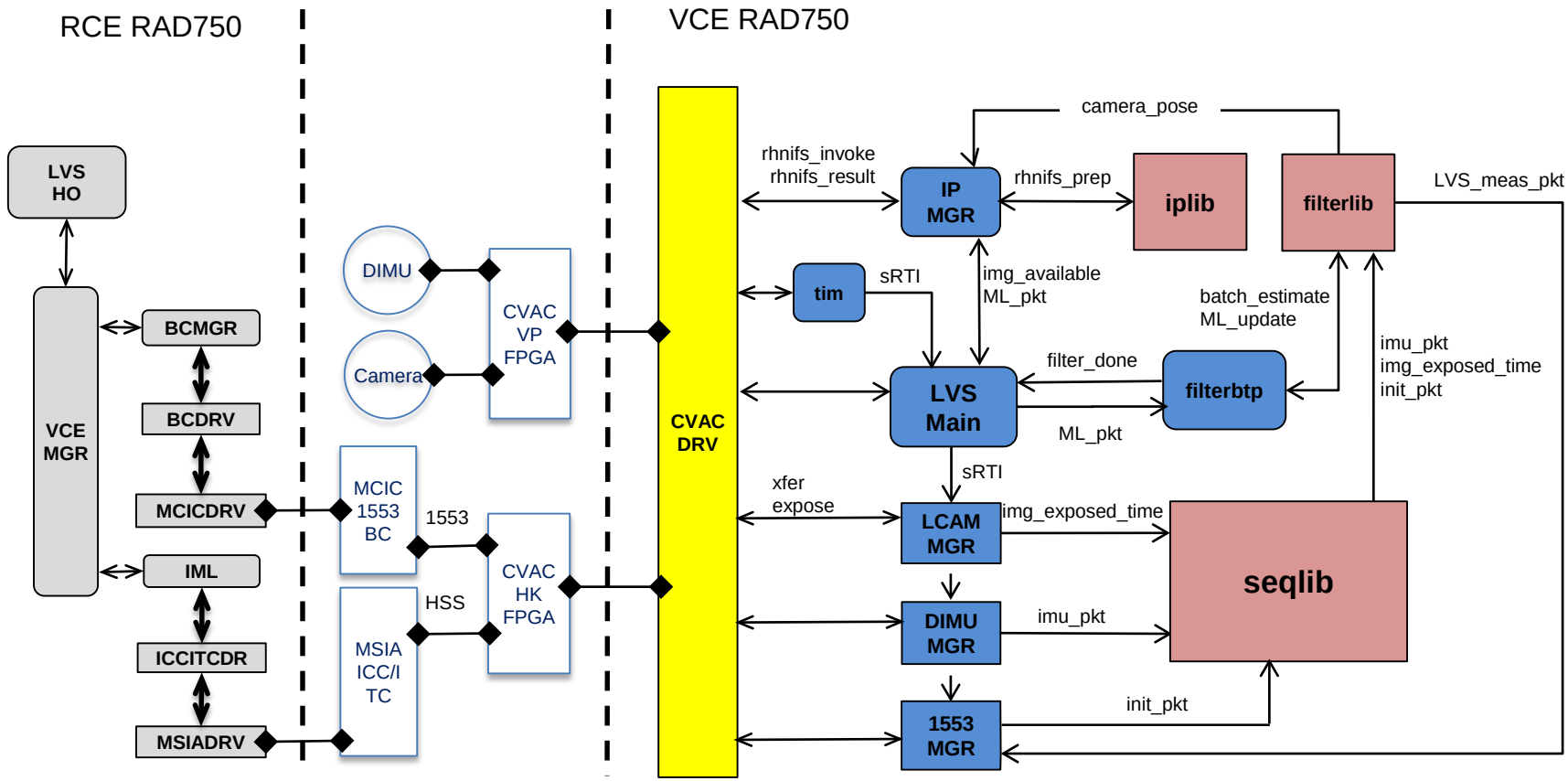
Kim P. Gostelow
James Montgomery
May 3, 2016

rhnifs =
- Radial Distortion Correction
- Homography Warp
- Image Normalization
- Interest Operator
- FFT Correlation
- Spatial Correlation

Hardware
Sensor
Device Driver/Library Module
Task Module
Event w/ data

RCE FSW
VCEFSW
VCEFSW Driver
MRL



LVS Operations Timeline

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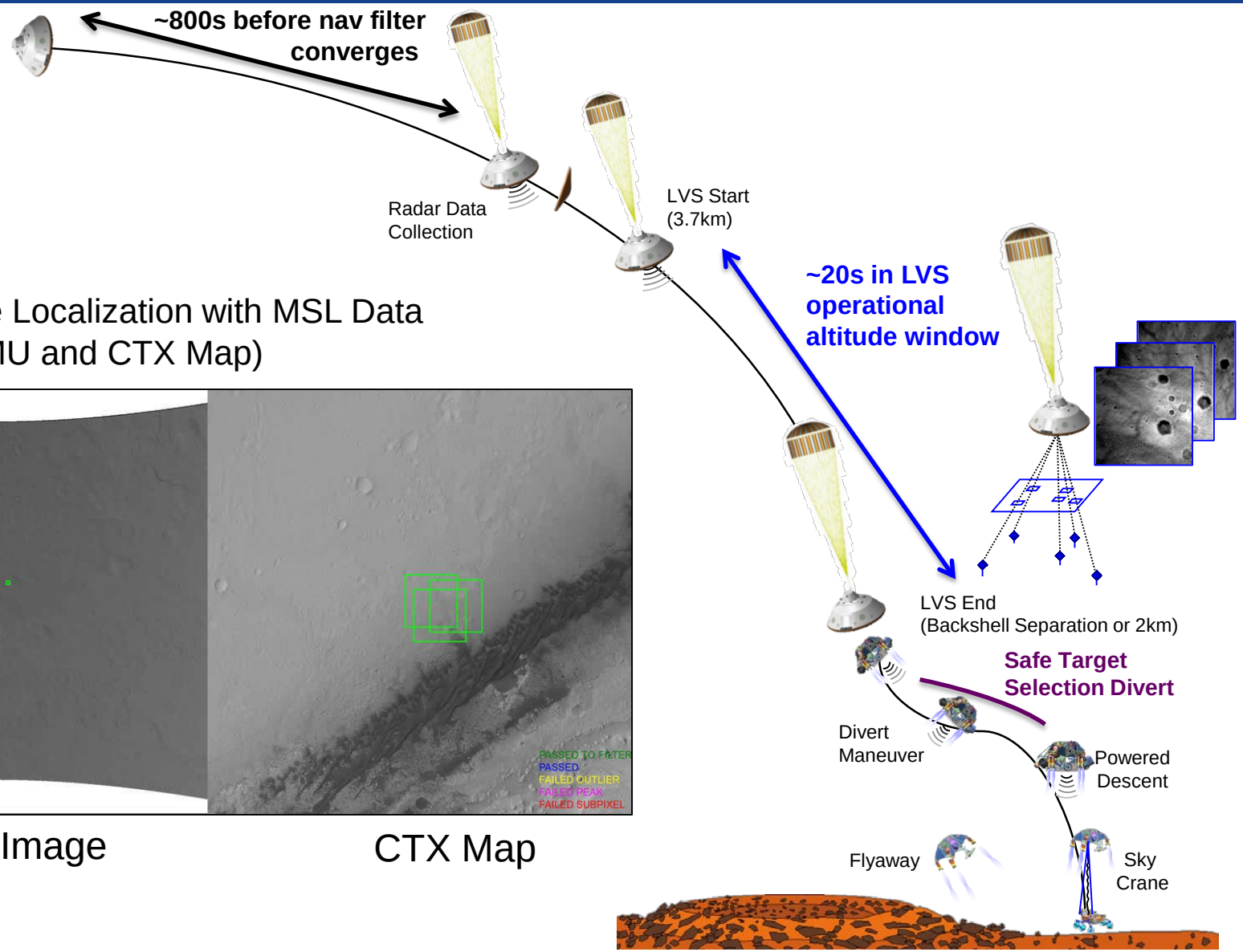
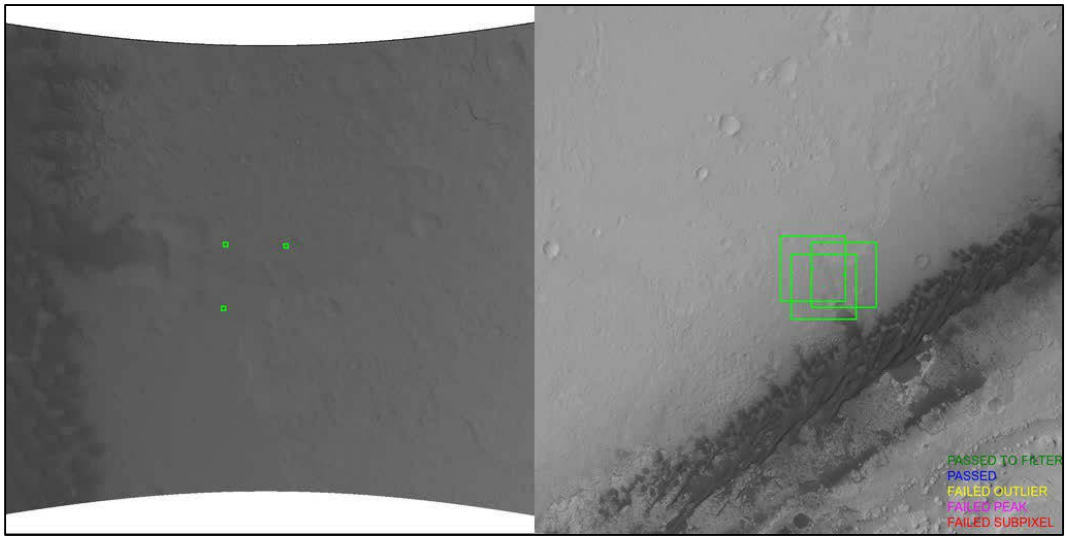


Map Relative Localization with MSL Data (MARDI, DIMU and CTX Map)



MARDI Image

CTX Map

5 Landmark Movie: CZ02.1.6 Movie

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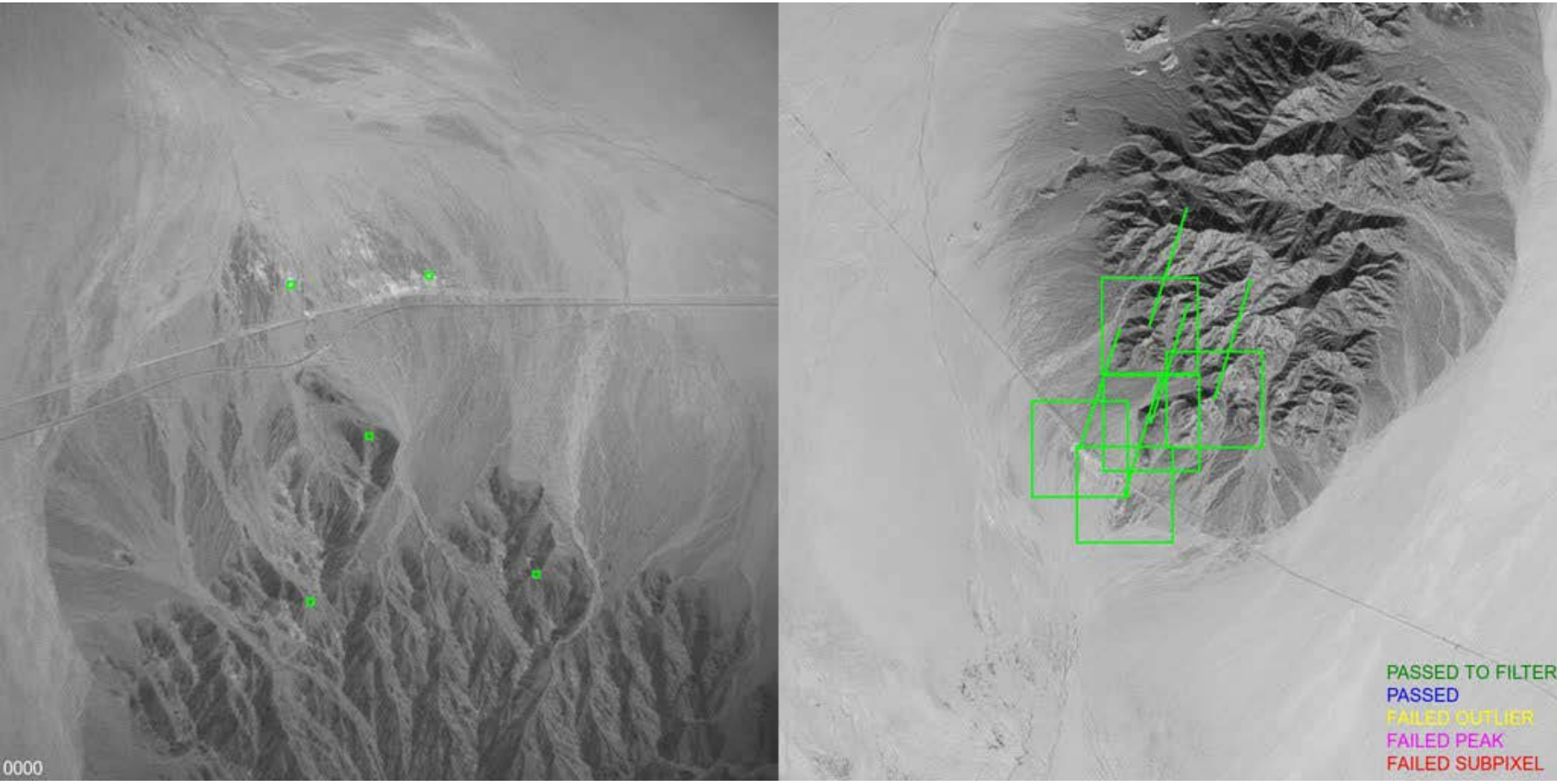
- Significant terrain relief
- 20 degree elevation angle with terrain relief



Horizontal Position Error Scatter Plot
After Fine Match and EKF (8 images total)

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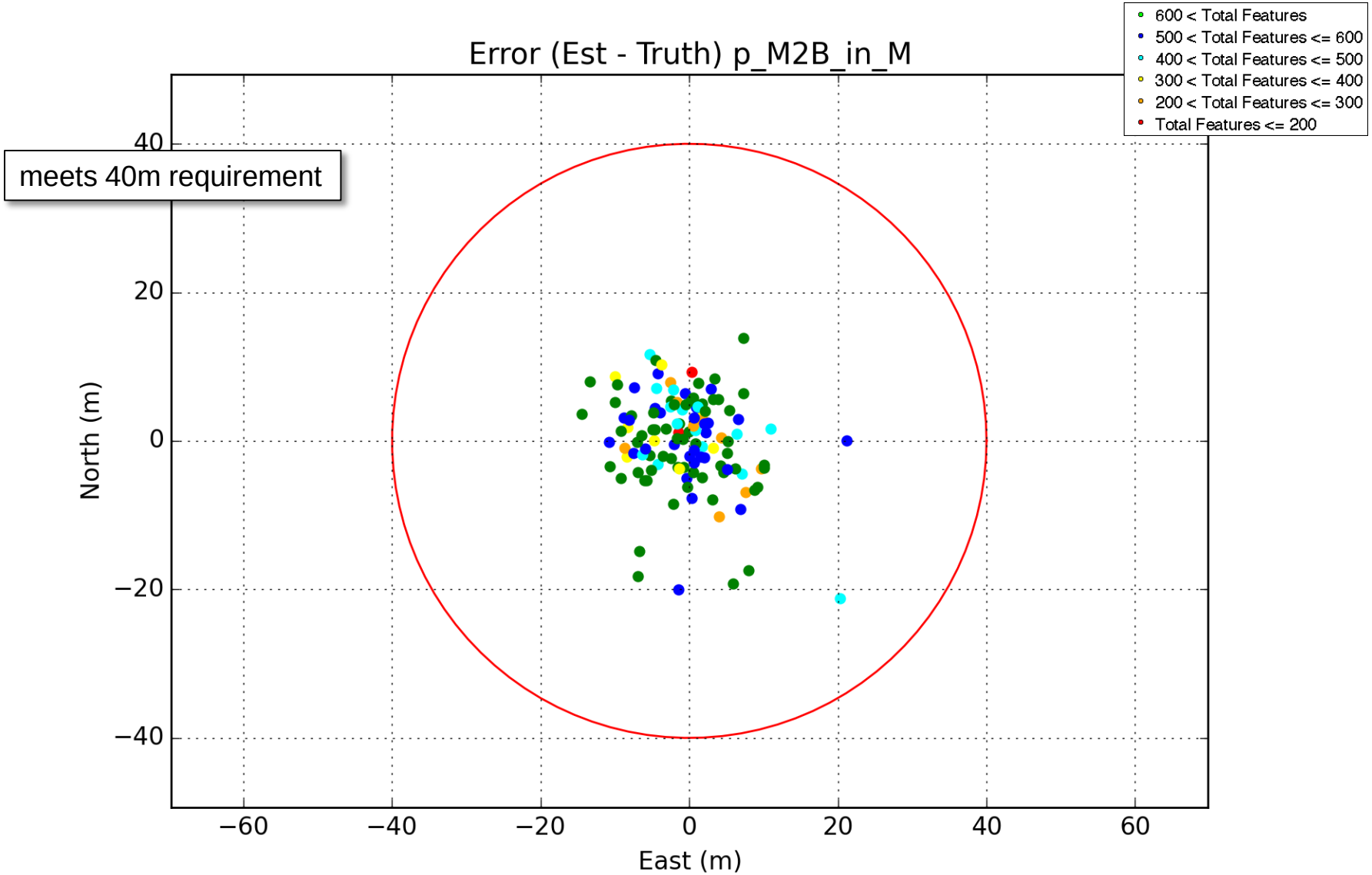

BACKUP

LVS Architecture

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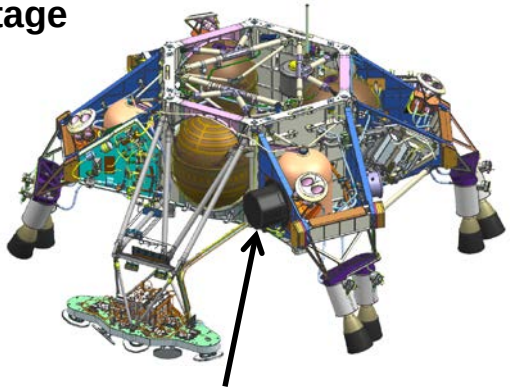
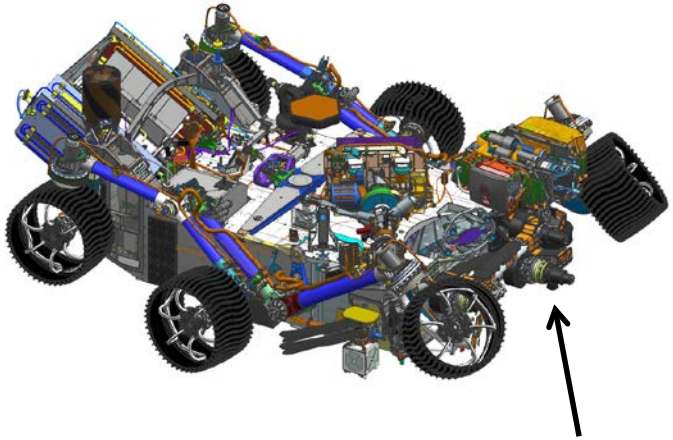
LVS operates during parachute descent when descent stage and rover are attached and inside backshell

Descent Stage



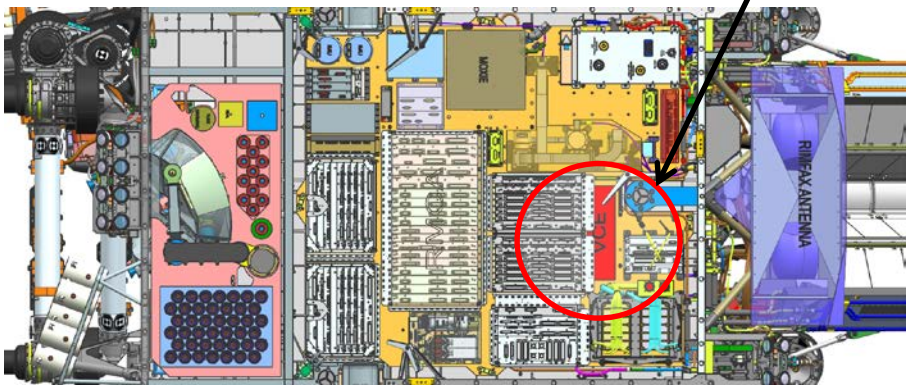
LVS uses the Descent IMU (DIMU) on the descent stage

Rover



LVS camera (LCAM) is on rover, 90˚ FOV

The VCE is inside the rover.



LVS Flight Interfaces

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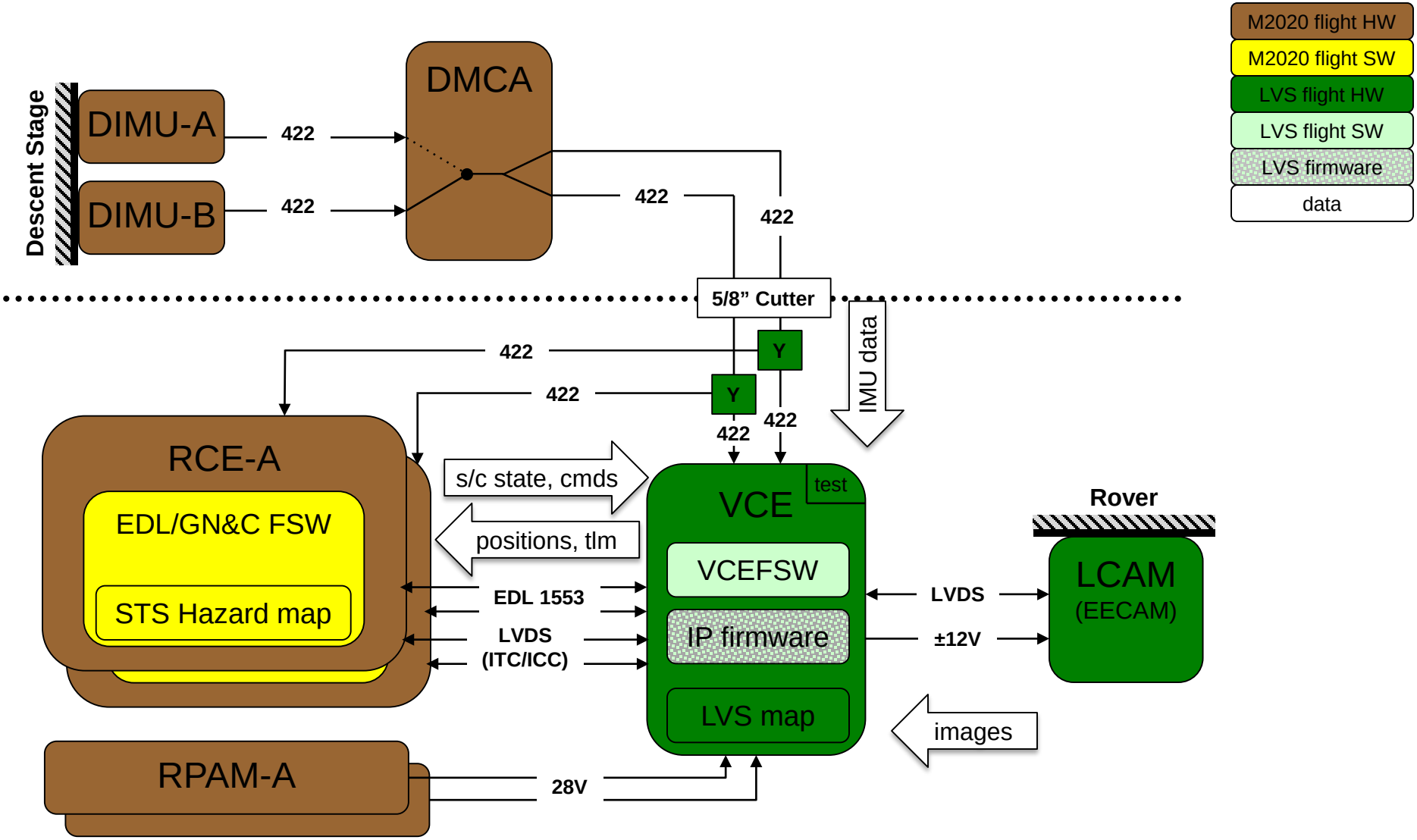
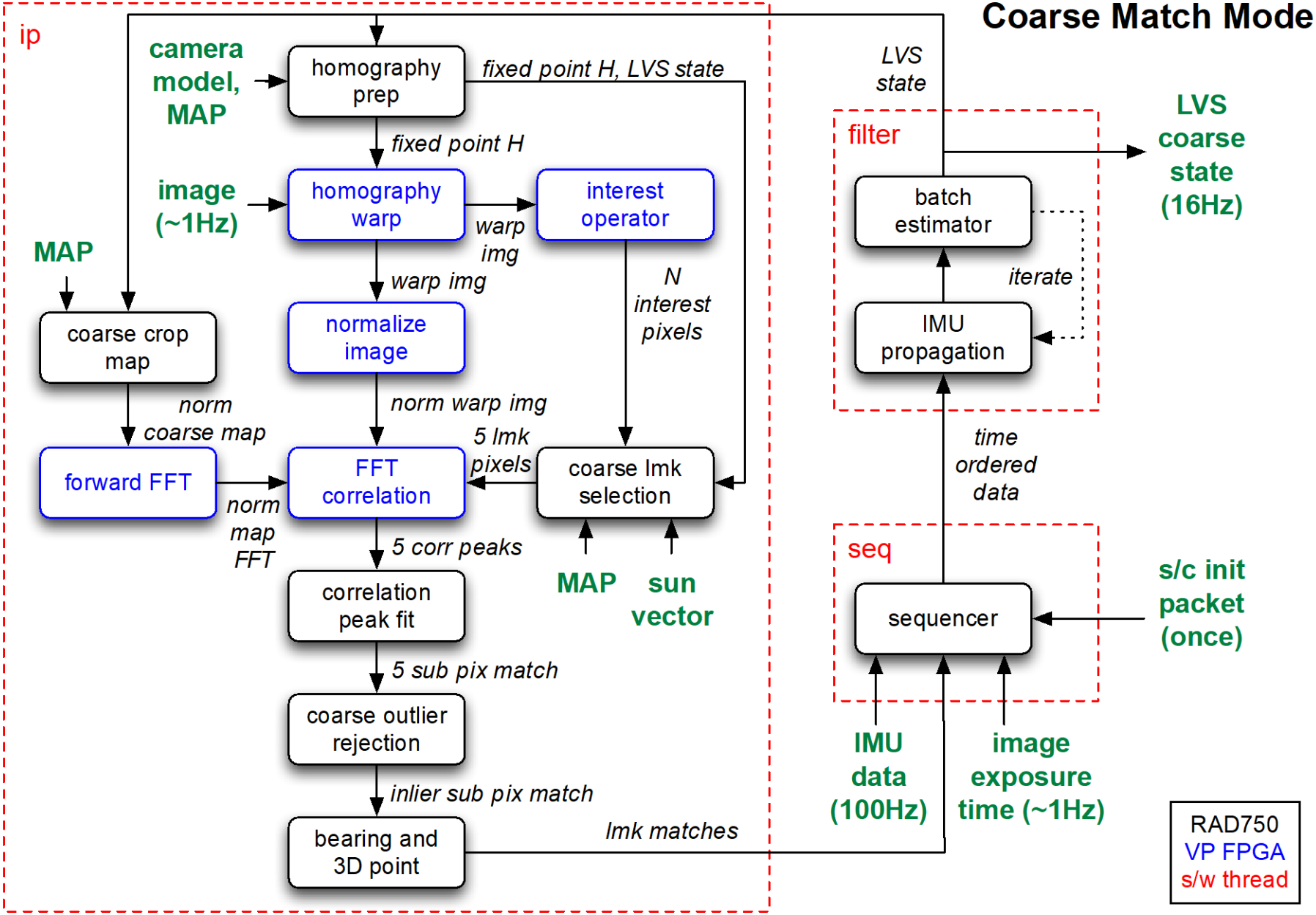
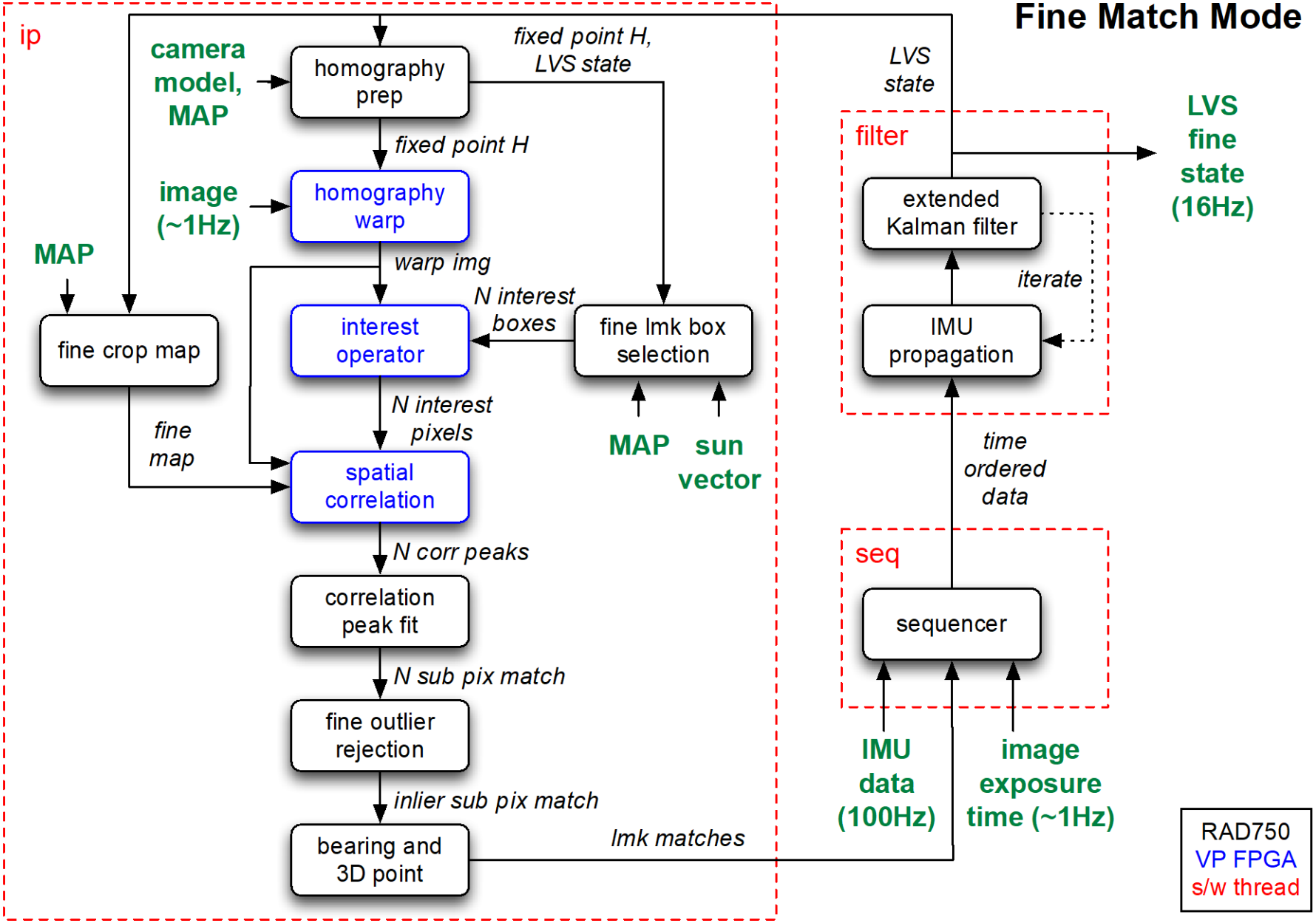


Coarse Match Mode



Fine Match Mode