Sensor head for autonomous planetary exploration

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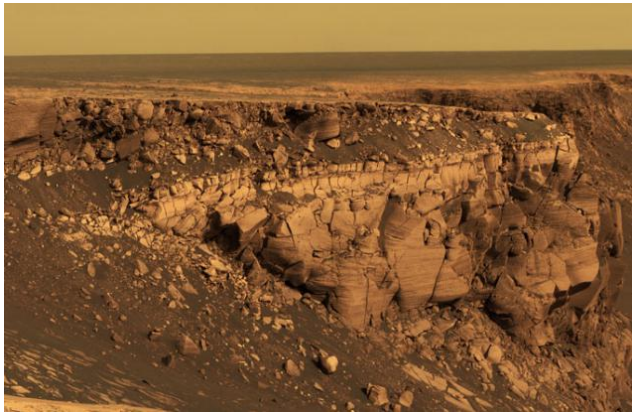
Motivation

- We want to go here …
- We need mobile exploration systems
- We need autonomy
- We need navigation
- In future: We need more ‘intelligence’



Rim of the Victoria-crater on Mars imaged by rover „Opportunity“, © NASA/JPL/Cornell University/University of Arizona/Ohio State University

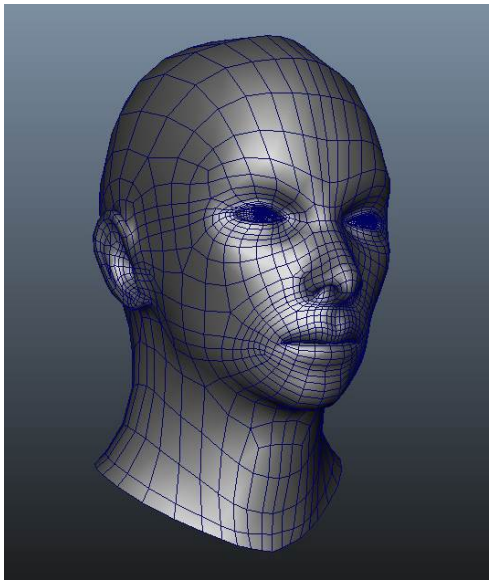
Crawler, © DLR

Lunar pit on Mare Tranquillitatis, observed by Lunar Reconnaissance Orbiter, © NASA/Arizona State University

Challenges

- What is special about navigation on planets/ asteroids?
  - no GPS
  - no infrastructure
  - no (or just coarse) landmarks
  - no maps

- Approach
  - sensors on a mobile robot
  - human head as an inspiring example
    - eyes
    - ears



IPS – System overview

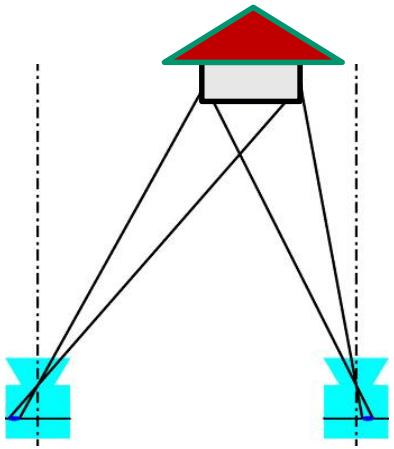
- DLR developed a multi-sensor head for navigation and 3D modelling
- generates ego-pose in 6DoF ($\boldsymbol{x}$, α) at any time in real-time
- no external reference needed
- compact: 4kg, 25 x 15 x 15cm³, adaptable to other sizes
- core feature: data processing
- prerequisites
    - synchronization
    - calibration
    - registration

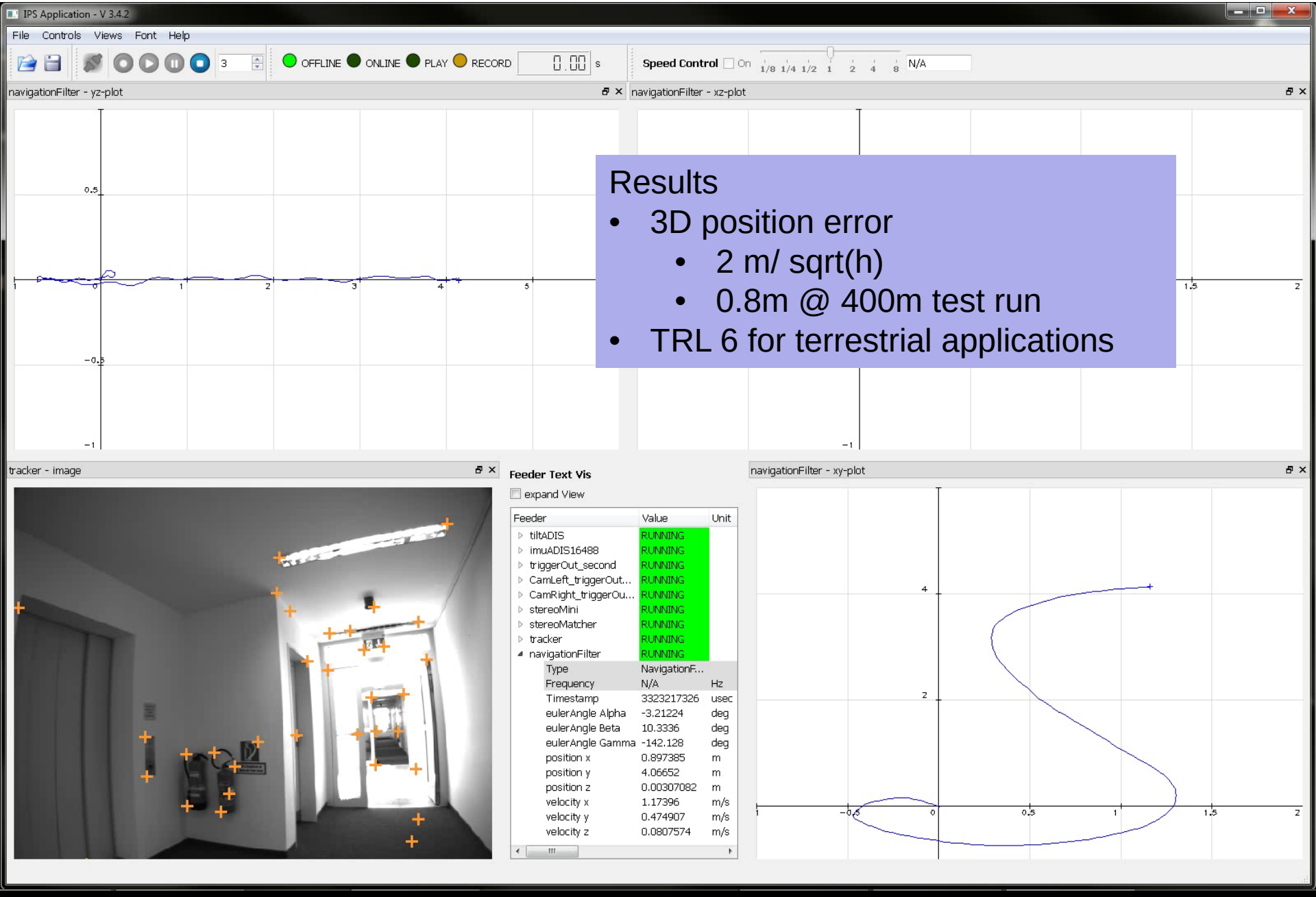
Parameters (example)

- Cameras
    - Panchromatic, 8 bit
    - 1200 x 800 pix, 90 deg FoV
    - 10 fps
- IMU
    - 400Hz
- Lamps
- Double-core CPU
- Off-the-shelf/ low-cost components

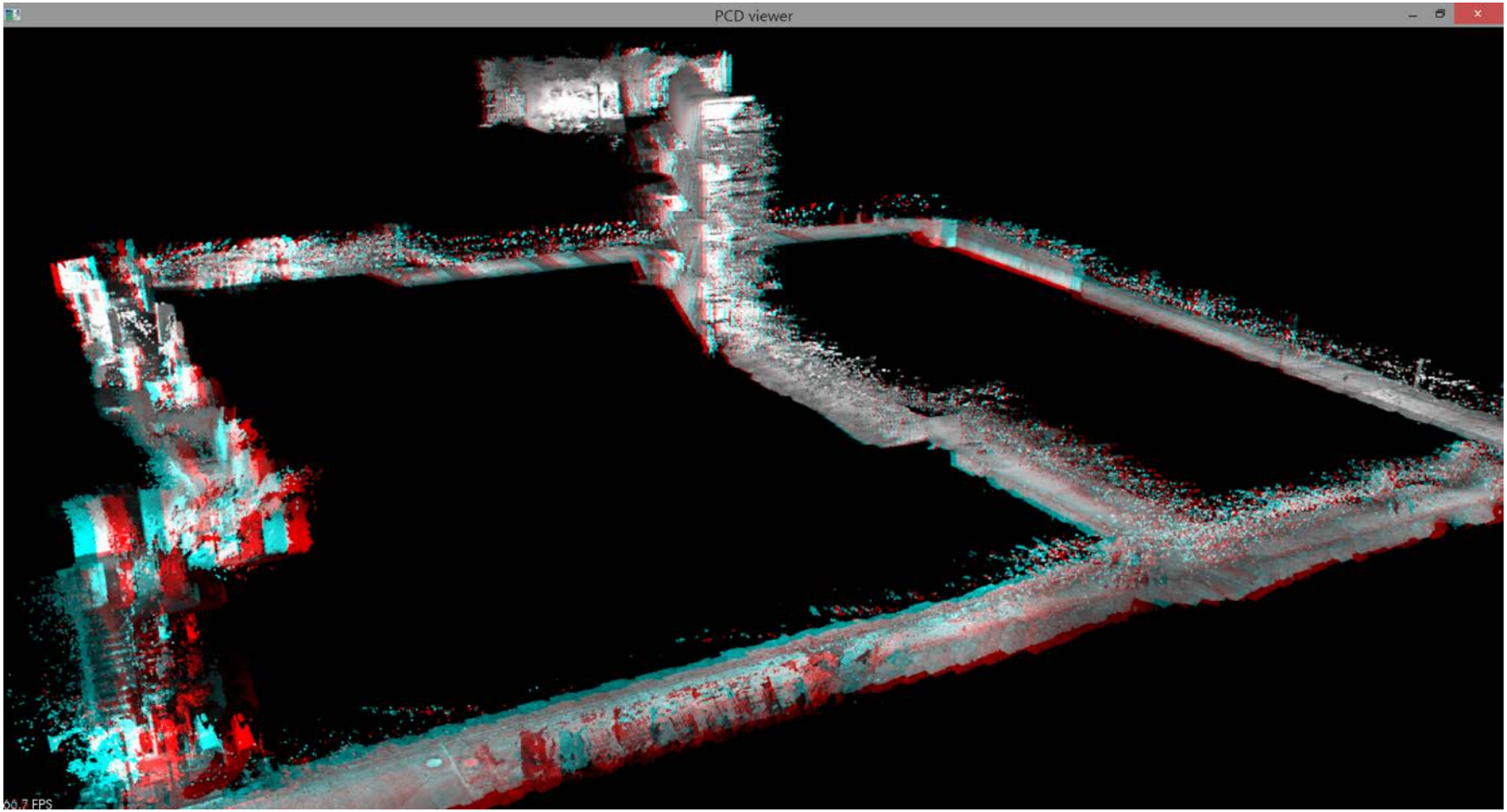
IPS – Measuring principle

- Inertial measurement unit (IMU)
  - measures acceleration + angular velocity
  - onefold/ twofold integration to position and orientation
  - strapdown algorithm
- Stereo camera
  - detection and tracking of natural landmarks
  - 3D point reconstruction
  - estimation of relative ego-motion
- Filtering and 6DoF state estimation




IPS Application - V 3.4.2
File Controls Views Font Help
OFFLINE ONLINE PLAY RECORD
Speed Control On
navigationFilter - yz-plot
navigationFilter - xz-plot
Results
• 3D position error
• 2 m/ sqrt(h)
• 0.8m @ 400m test run
• TRL 6 for terrestrial applications
tracker - image
Feeder Text Vis
expand View
Feeder Value Unit
tiltADIS RUNNING
imuADIS16488 RUNNING
triggerOut_second RUNNING
CamLeft_triggerOut... RUNNING
CamRight_triggerOu... RUNNING
stereoMini RUNNING
stereoMatcher RUNNING
tracker RUNNING
navigationFilter RUNNING
Type NavigationF...
Frequency N/A Hz
Timestamp 3323217326 usec
eulerAngle Alpha -3.21224 deg
eulerAngle Beta 10.3336 deg
eulerAngle Gamma -142.128 deg
position x 0.897385 m
position y 4.06652 m
position z 0.00307082 m
velocity x 1.17396 m/s
velocity y 0.474907 m/s
velocity z 0.0807574 m/s
navigationFilter - xy-plot

IPS – 3D capabilities



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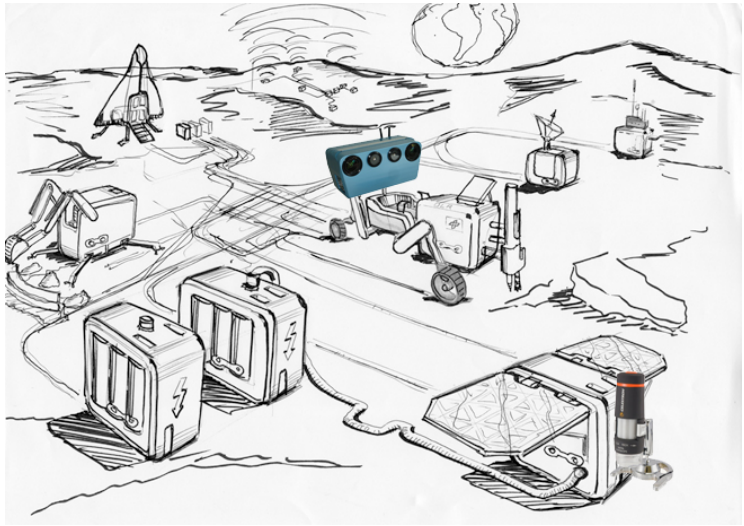
IPS – Applications in space

- On-orbit servicing
  - inspection
  - rendezvouz and docking
  - space debris removal

- Planetary exploration
  - navigation
  - 3D modelling
  - referencing of science data



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IPS – Applications on Earth

- Mining
- (Industrial) facility management
- Vehicles (cars, rail vehicle)
- Forestry