TOOL FOR REAL-TIME PREDICTION OF IXV TRAJECTORY IN THE MISSION CONTROL CENTER

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IXV Key facts

Agency: ESA
Prime: TASI

LEO Re-entry representative

L/D ≈ 0.7

Weight 1840kg

Ceramic and ablative TPS

>40 partners

3 ground stations

L/D = 0.7

Length 5.5m

Launched by VEGA from Kourou

3 parachute stages

11th February 2015

Aerodynamic experiments

Recovered in SE Pacific

Guided entry

Aerodynamic actuators

Images: Courtesy of ESA and TASI
IXV Mission Profile

Reference Trajectory 3D view

Reference Timeline
1 – Lift off
2 – Separation
3 – Entry gate
4 – Descent gate
5 – Splashdown

T = 0 [s]  
Ascent segment  1130 [s]

T = 1130 [s]  
Orbital segment  2769 [s]

T = 3899 [s]  
Re-entry segment  1213 [s]

T = 5112 [s]  
Descent segment  685 [s]
IXV Mission Profile

Reference Trajectory 3D view

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1 – Lift off  
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<table>
<thead>
<tr>
<th>Event</th>
<th>Time (s)</th>
<th>Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lift off</td>
<td>T = 0</td>
<td>Ascent segment 1130 [s]</td>
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<td>T = 5112</td>
<td>Descent segment 685 [s]</td>
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<tr>
<td>Splashdown</td>
<td>T = 6105</td>
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</tbody>
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Trajectory Monitoring needs in the Mission Control center

- Monitor vehicle’s startup and prelaunch events by TM
- Monitor vehicle’s state during the flight by TM
- Propagate the trajectory and visualize for the operators
  - Including when out of visibility windows
- Provide the naval ground station with the pointing data (DO)
- Assist localization and recovery after the splashdown
- Monitor and predict vehicle’s state in case of anomalies

IXV MCC during the mission

TPVT and GNC Consoles in foreground
TPVT introduction

- TPVT = Trajectory Propagation and Visualization Tool
- Dedicated development
- An efficient and low cost solution was put in place
  - Development of a dedicated propagation core and graphic user interface
  - Visualization based on STK visualization engine
  - Running on commercial workstations in MCC
- Propagates trajectory from the actual point until splashdown whenever a fresh TM is available from IXV or VEGA
- Transmits vehicle’s predicted state at 10Hz, updates the trajectory at 0.5Hz
TPVT architecture and dataflow
Propagator module (1/2)

Development
- Developed in Simulink,
  - autocoded and compiled and integrated as Dynamic Link library

Features:
- 3DOF propagation in Cartesian reference frame
- Aerodynamic and environment models the same as used for IXV development, updated environment profiles uploaded from soundings
- Guidance algorithms and parameters the same as for real IXV
Propagator module (2/2)

- Output of the TPM: trajectory profile until splashdown
- The closed-loop guidance of re-entry outputs bank profile:

![Graph showing bank profile generated by the guidance]

- Dedicated attitude performance model has been developed for the descent phase, based on bank angle and roll/yaw rates

![Graph showing behavior as simulated by 12DOF Multi-body simulator]

![Graph showing model used to approximate the bank rate under supersonic drogue]
Graphic user interface

Based on JAVA

GUI functions and features
- Monitoring of main events
- Start/stop operations
- Load trajectory and meteo profiles
- Configure network settings
- Trim network delay
- Set launch time
- Manually select mission phase
- Manually select TM source
- Manually introduce initial conditions (from FAX, or GNC MIMCS)

Information panel
Operations tabs
Set-up and log tabs
Graphic user interface

Example of GUI windows

- Phase selector
- Propagation source
- Manual initial conditions
- Event's log
Visualization features

- 2D globe map
- Downrange and time information
- 3D attitude
- Visibility from antennas
- Splashdown area
Visualization features

- 2D globe map zoomed
- Downrange and time information
- Vehicle under parachute
- Visibility from ship
- Splashdown area
Propagation performance

Analyzed for selected points:
1. 1st VEGA DO packet
2. last VEGA DO packet, before IXV TM became available
3. first packet after separation
4. last packet before Malindi LoS
5. 1st packet after NAVAL AoS
6. 1st packet after DRS triggering
7. Last received packet

Distance error (between propagated and real vehicle’s splashdown point)

Azimuth elevation profiles for type propagated trajectories

Predicted splashdown position together with the 25km circle (accuracy requirement), SRA and NOTAM/AVURNNAV area
Conclusions

Dedicated development

GNC, AEDB etc.

Low cost

High accuracy and representability

Visualization and essential information

TPVT

Future applications (PRIDE, eDeorbit, sample return etc)
15 hours in 2 minutes!

Thank you!!!