

WE LOOK AFTER THE EARTH BEAT

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

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ThalesAlenia
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IXV Key facts

Agency: ESA
Prime: TASI

L/D \approx 0.7

Weight 1840kg

Ceramic and
ablative TPS

>40 partners

LEO Re-entry
representative

L/D = 0.7

Length 5,5m

Launched by VEGA
from Kourou

Aerodynamic
experiments

Aerodynamic
actuators

Recovered in SE Pacific

Guided entry

3 ground
stations

3 parachute stages

11th February 2015

Images: Courtesy of ESA and TASI

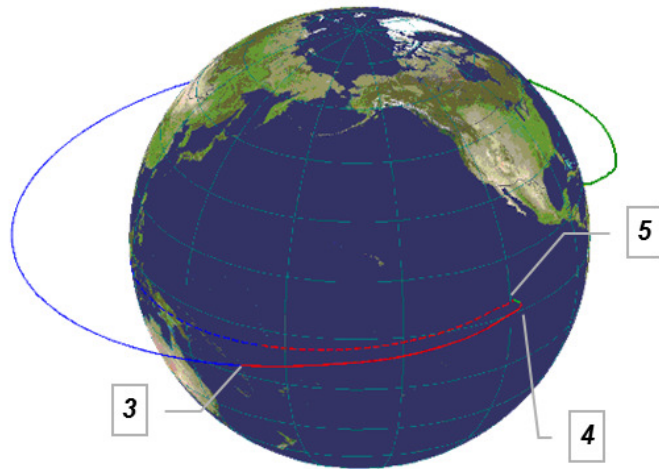
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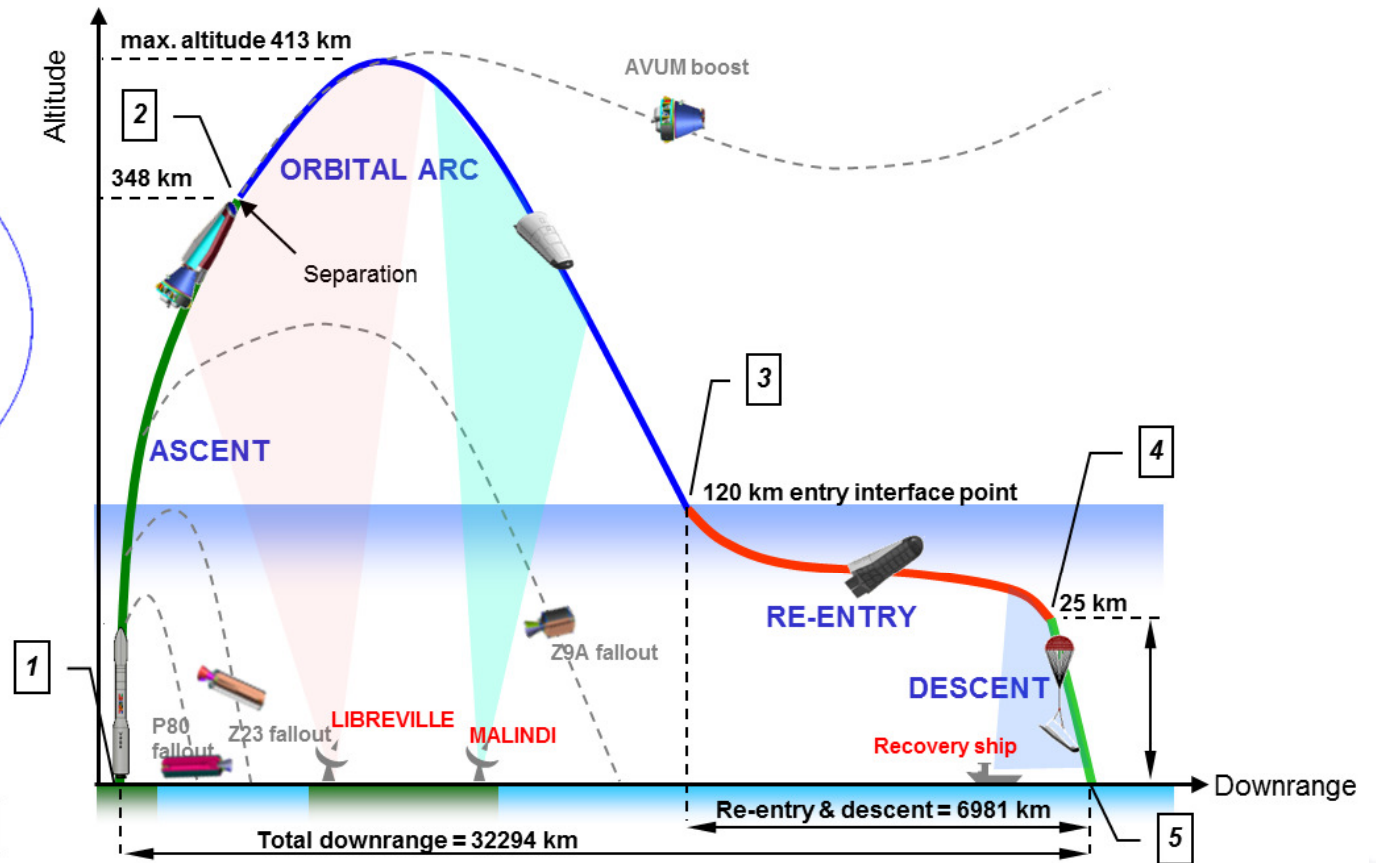
IXV Mission Profile



Reference Trajectory 3D view



[Altitude scale: 10X]



Reference Timeline

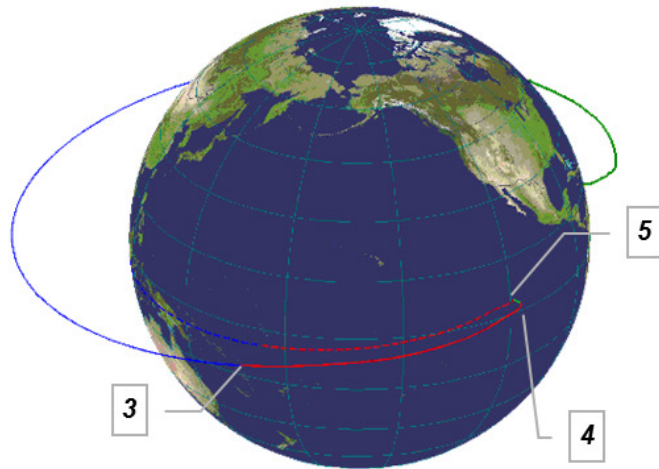
1 – Lift off	T = 0 [s]		
2 – Separation	T = 1130 [s]	→	Ascent segment 1130 [s]
3 – Entry gate	T = 3899 [s]	→	Orbital segment 2769 [s]
4 – Descent gate	T = 5112 [s]	→	Re-entry segment 1213 [s]
5 – Splashdown	T = 6105 [s]	→	Descent segment 685 [s]

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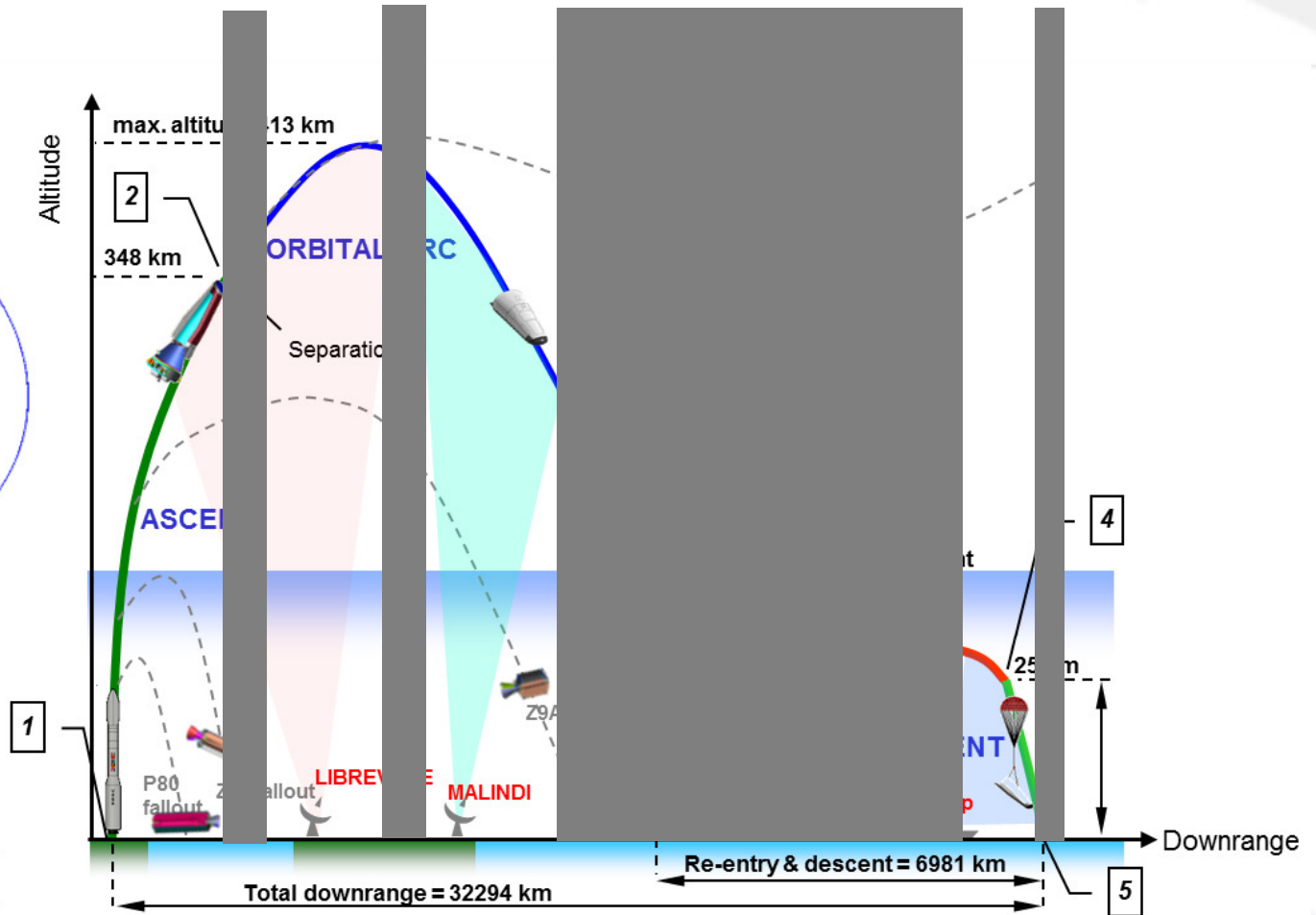
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Trajectory Monitoring needs in the Mission Control center

- 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

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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

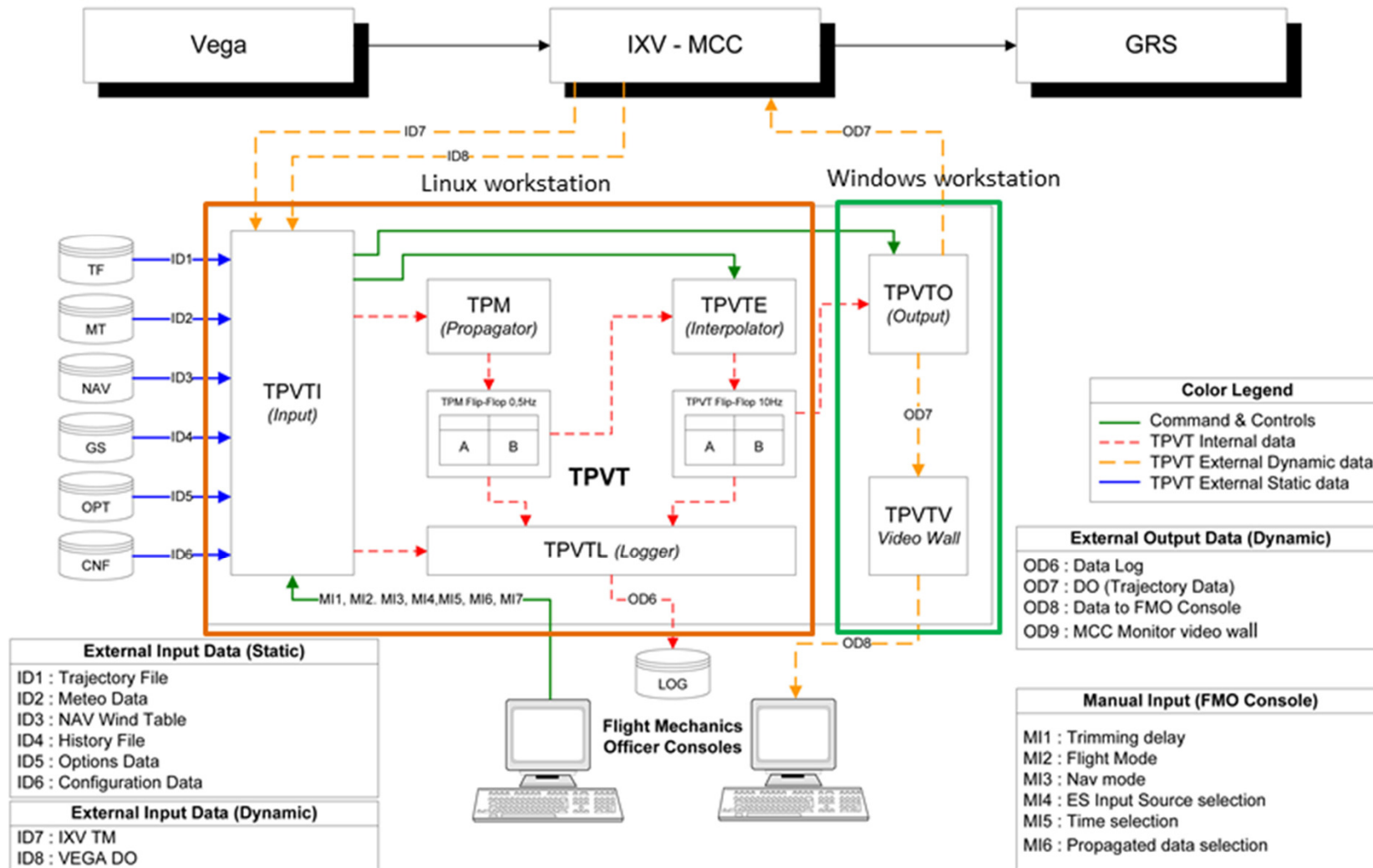
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TPVT architecture and dataflow



IXV - Main Data Flow Diagram

Progetto IXV

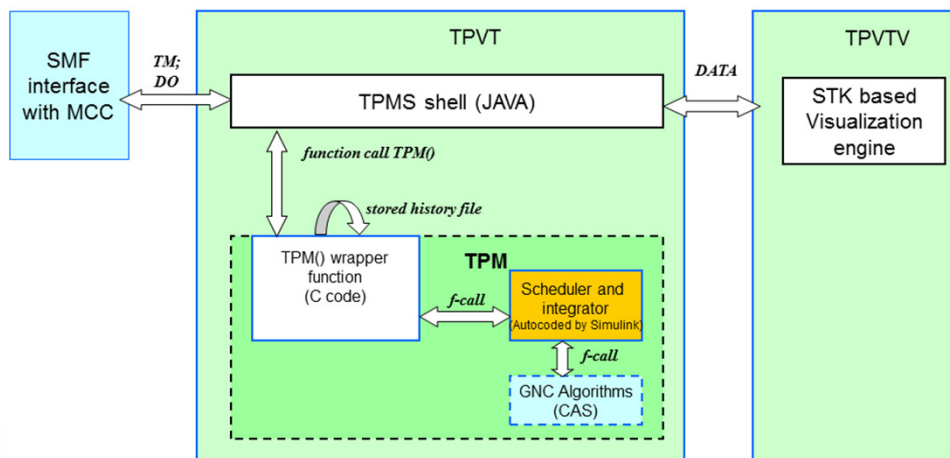


TPVT architecture overview

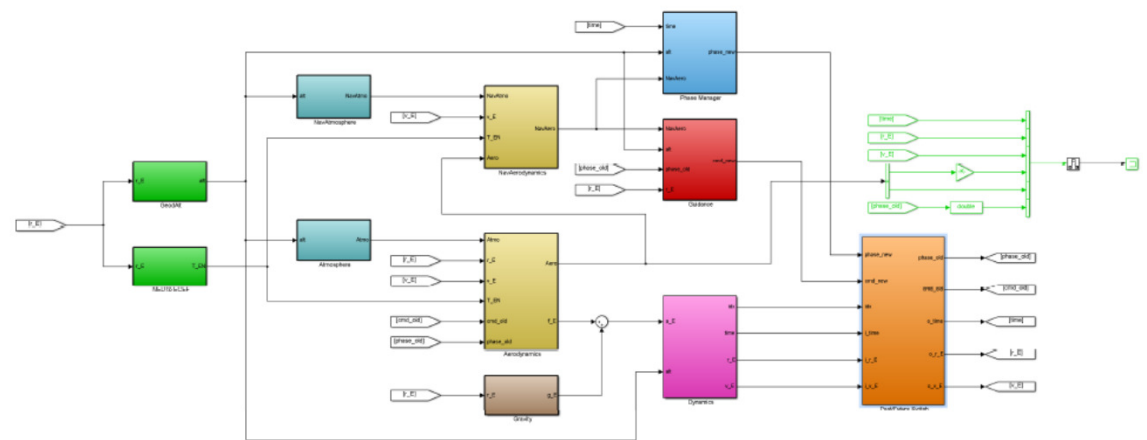
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Propagator module (1/2)

- 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



TPM and its internal and external interfaces

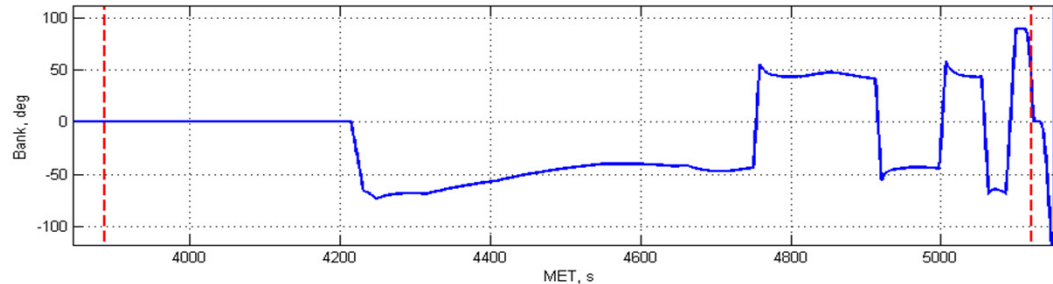


Simulink model of TPV

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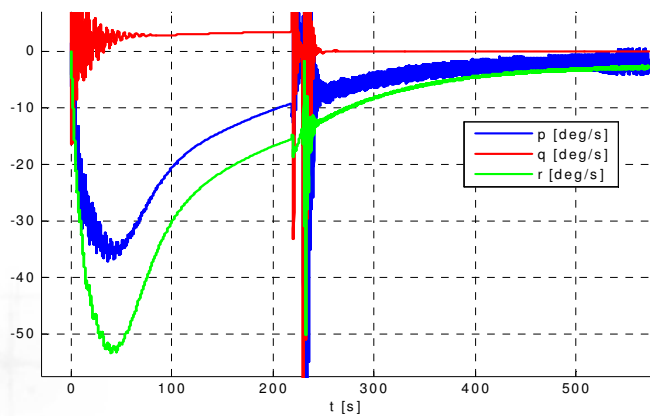
Propagator module (2/2)

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

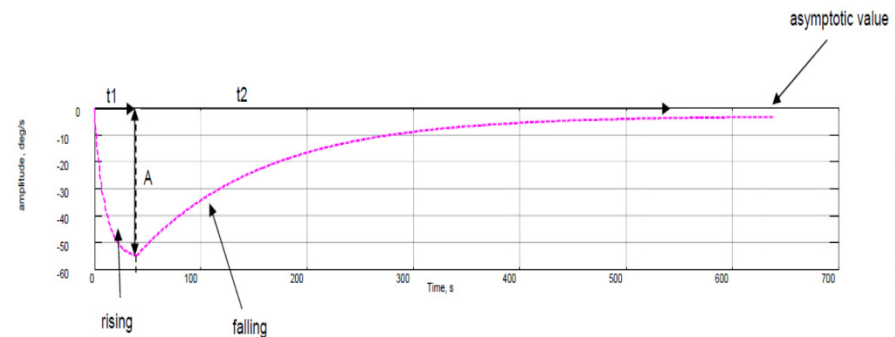


Bank profile generated by the guidance

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



Behavior as simulated by 12DOF Multi-body simulator

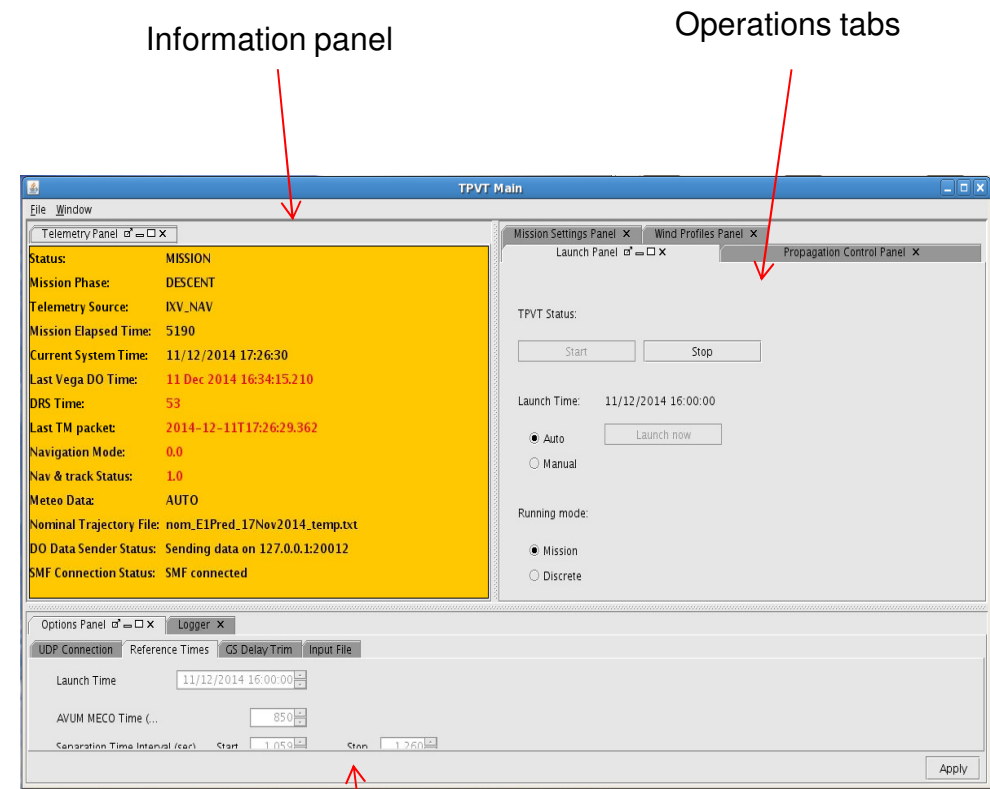


Model used to approximate the bank rate under supersonic drogue

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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)



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Graphic user interface

Example of GUI windows

Phase selector Propagation source

The screenshot shows the TPVT Main GUI with several panels and a log table. Red arrows point from external text labels to specific GUI elements.

Annotations:

- Phase selector:** Points to the "Mission Phase" section with radio buttons for Automatic and Manual, and a "Manual Selection" list containing Launchpad, Ascent, Orbital, Reentry, PreRelease, Descent, and Splashdown.
- Propagation source:** Points to the "Propagation Source" section with radio buttons for Automatic and Manual, and a "Manual Selection" list containing VEGA DO, IXV NAV, IXV GPS, Nominal, Selected, and Last Propagated.
- Manual initial conditions:** Points to the "Selected Instant" section, which includes a "MET" field (1000.0 s), radio buttons for Manual and Logged, and input fields for position (x, y, z) and velocity (x, y, z).
- Event's log:** Points to the "Logger" table at the bottom of the interface.

Event ID	Event Epoch (UTC)	Event Type	Event Text
1	04/09/2014 11:58:59	APPLICATION	Application started
2	04/09/2014 11:59:02	APPLICATION	Interpolation process started
3	04/09/2014 12:23:56	MODE_CHANGE	Manual propagation source enabled
4	04/09/2014 12:23:57	MODE_CHANGE	Propagation Source changed to IXV GPS
5	04/09/2014 12:24:23	MODE_CHANGE	Propagation Source changed to Last Propagated
6	04/09/2014 12:24:37	MODE_CHANGE	Auto propagation source enabled
7	04/09/2014 12:31:11	MODE_CHANGE	Manual propagation source enabled
8	04/09/2014 12:31:13	MODE_CHANGE	Propagation Source changed to IXV GPS

Manual initial conditions

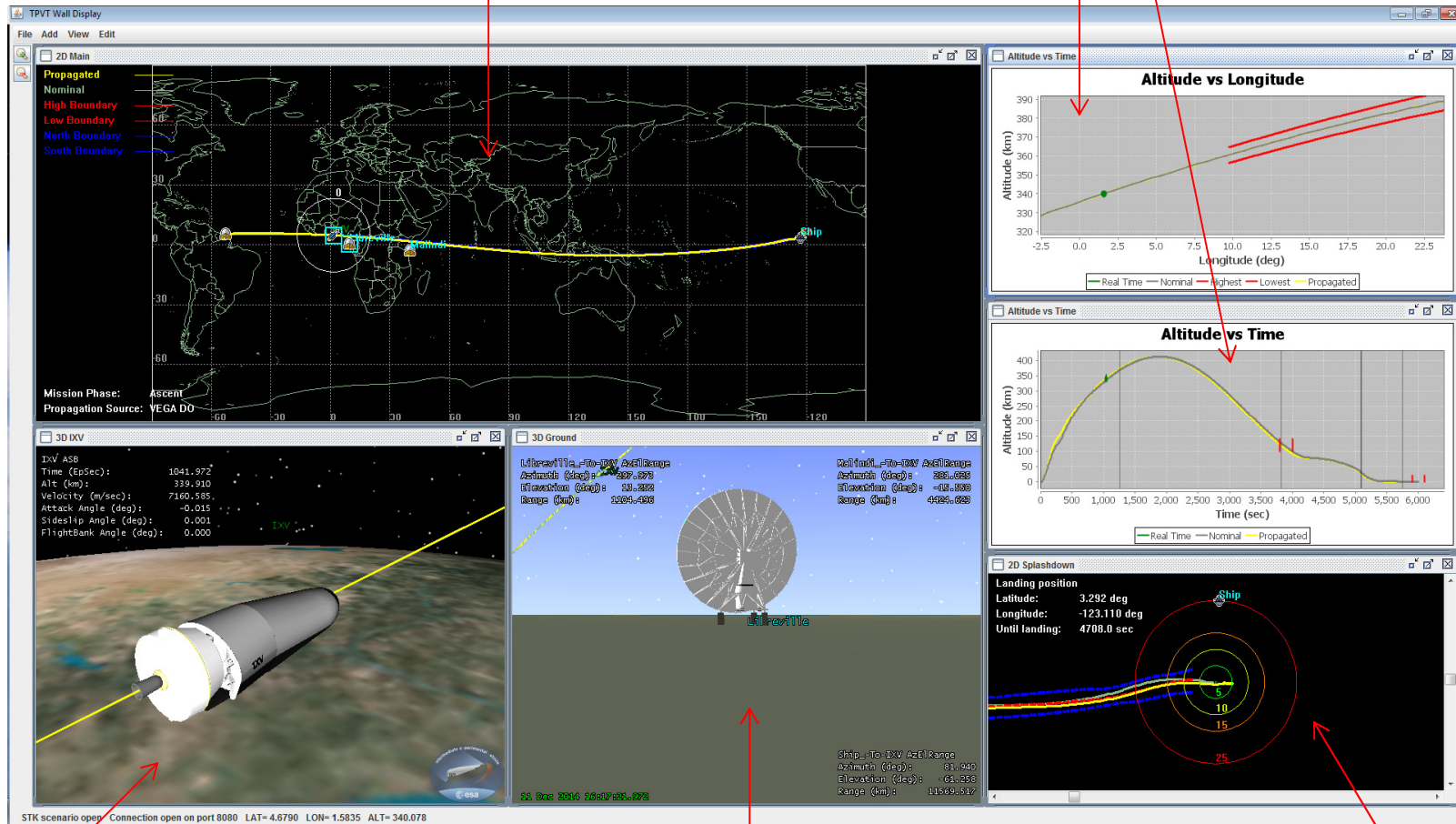
Event's log

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Visualization features

2D globe map

Downrange and time information



3D attitude

Visibility from antennas

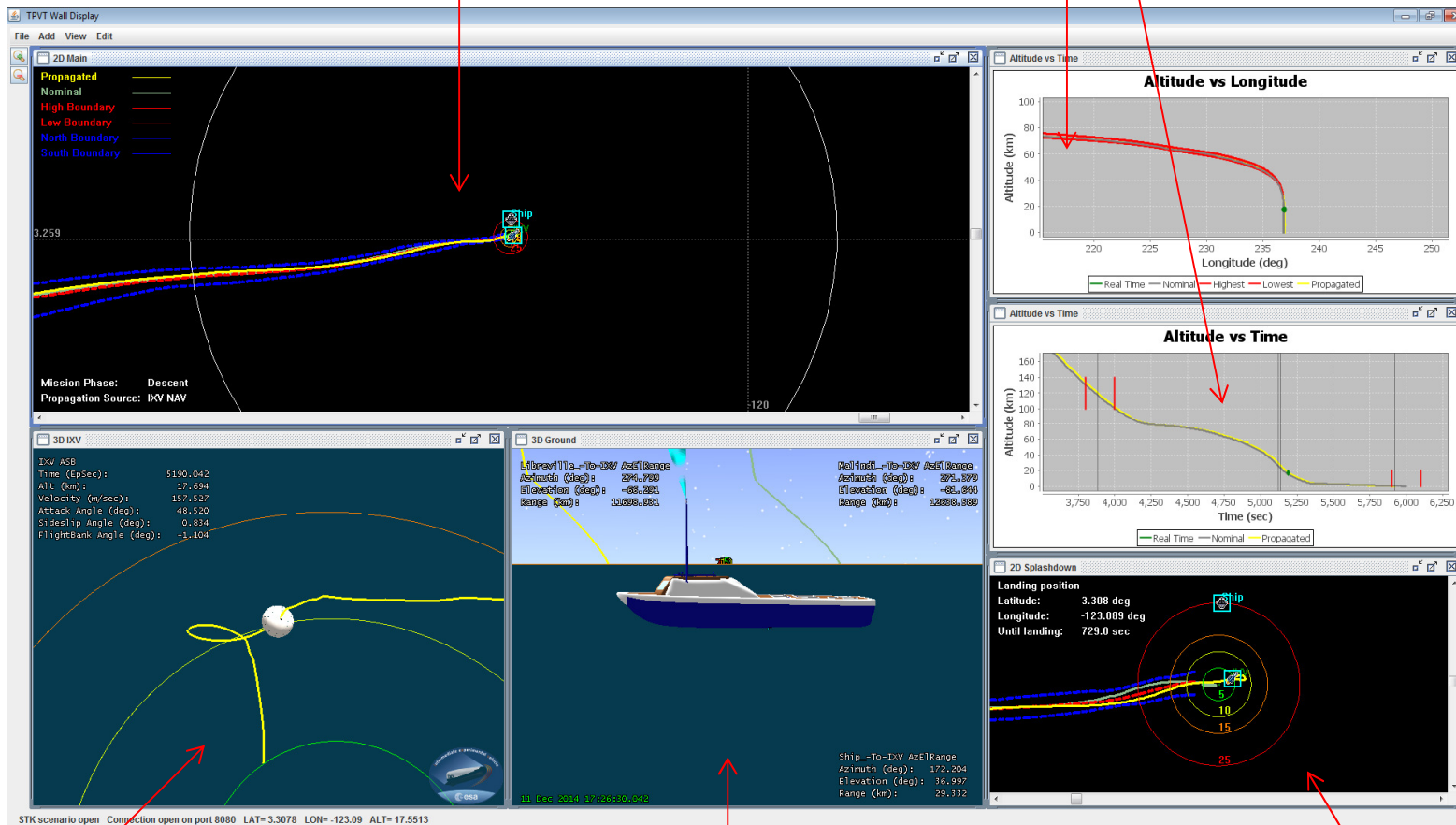
Splashdown area

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Visualization features

2D globe map zoomed

Downrange and time information



Vehicle under parachute

Visibility from ship

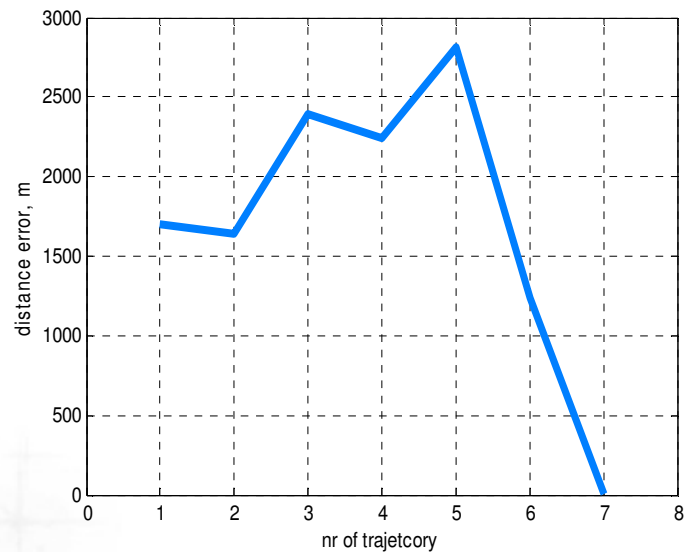
Splashdown area

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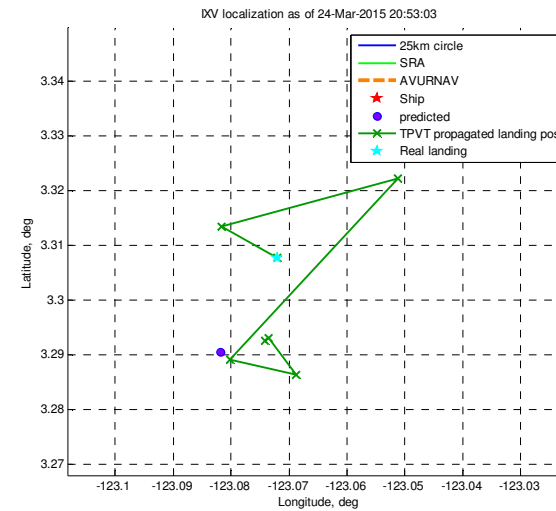
Propagation performance

Analyzed for selected points:

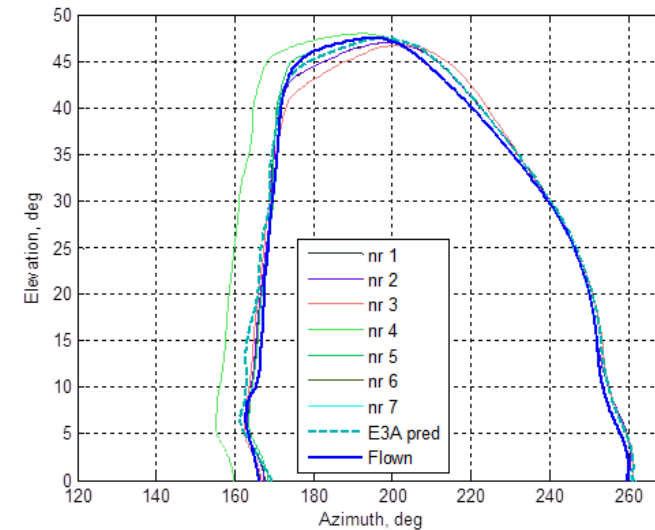
1. 1st VEGA DO packet
2. last VEGA DO packet, before IXV TM became available
3. first packet after separation
4. last packet before Malindi LoS
5. 1st packet after NAVAL AoS
6. 1st packet after DRS triggering
7. Last received packet



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



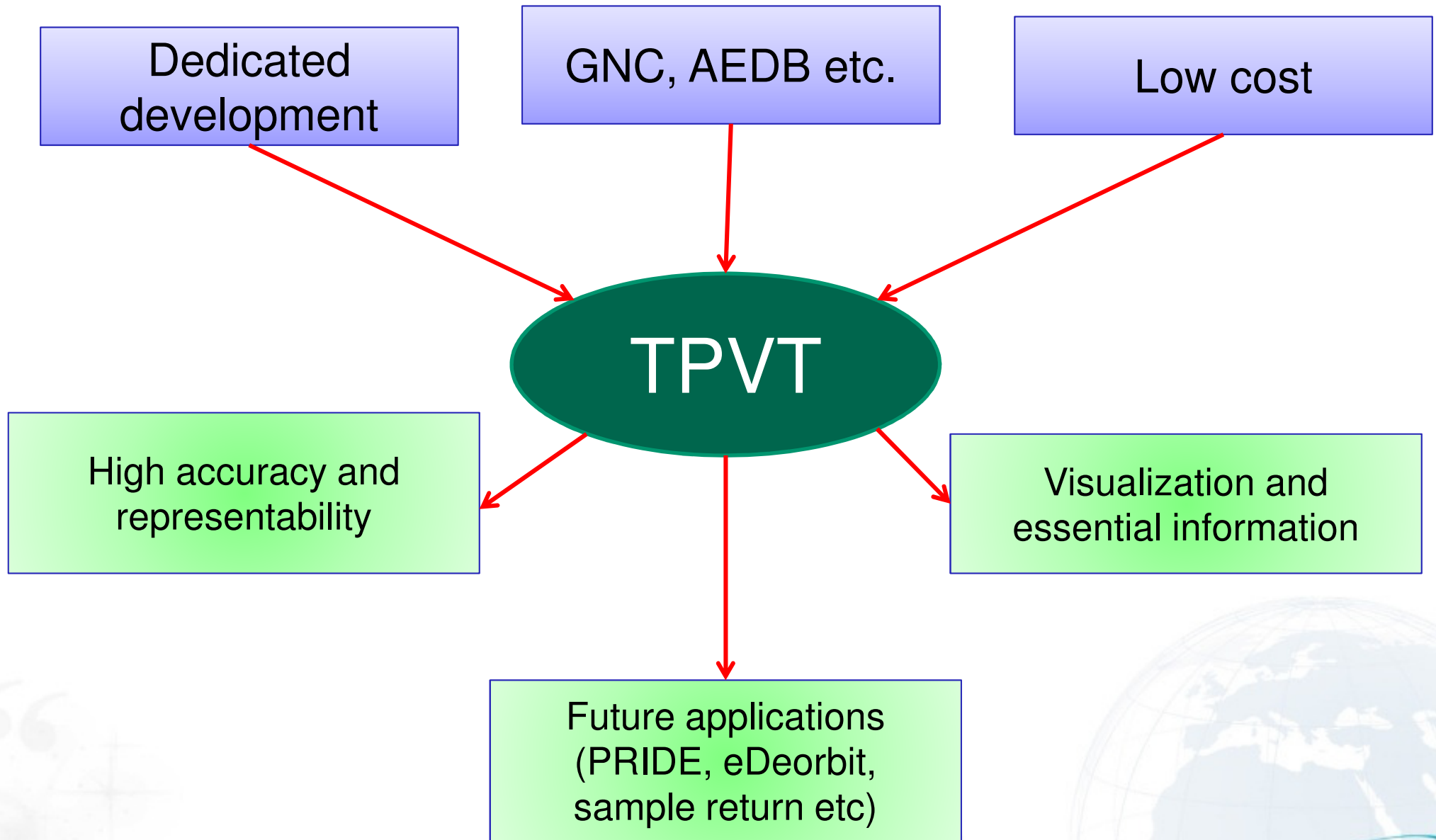
Predicted splashdown position together with the 25km circle (accuracy requirement), SRA and NOTAM/AVURNAV area



Azimuth elevation profiles for tyhe propagated trajectories

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Conclusions



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15 hours in 2 minutes!

Thank you!!!!



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