3rd International Planetary Probe Workshop

First Application of the DTWG Reconstruction Algorithm to REAL Huygens Flight Data

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DTWG Team History

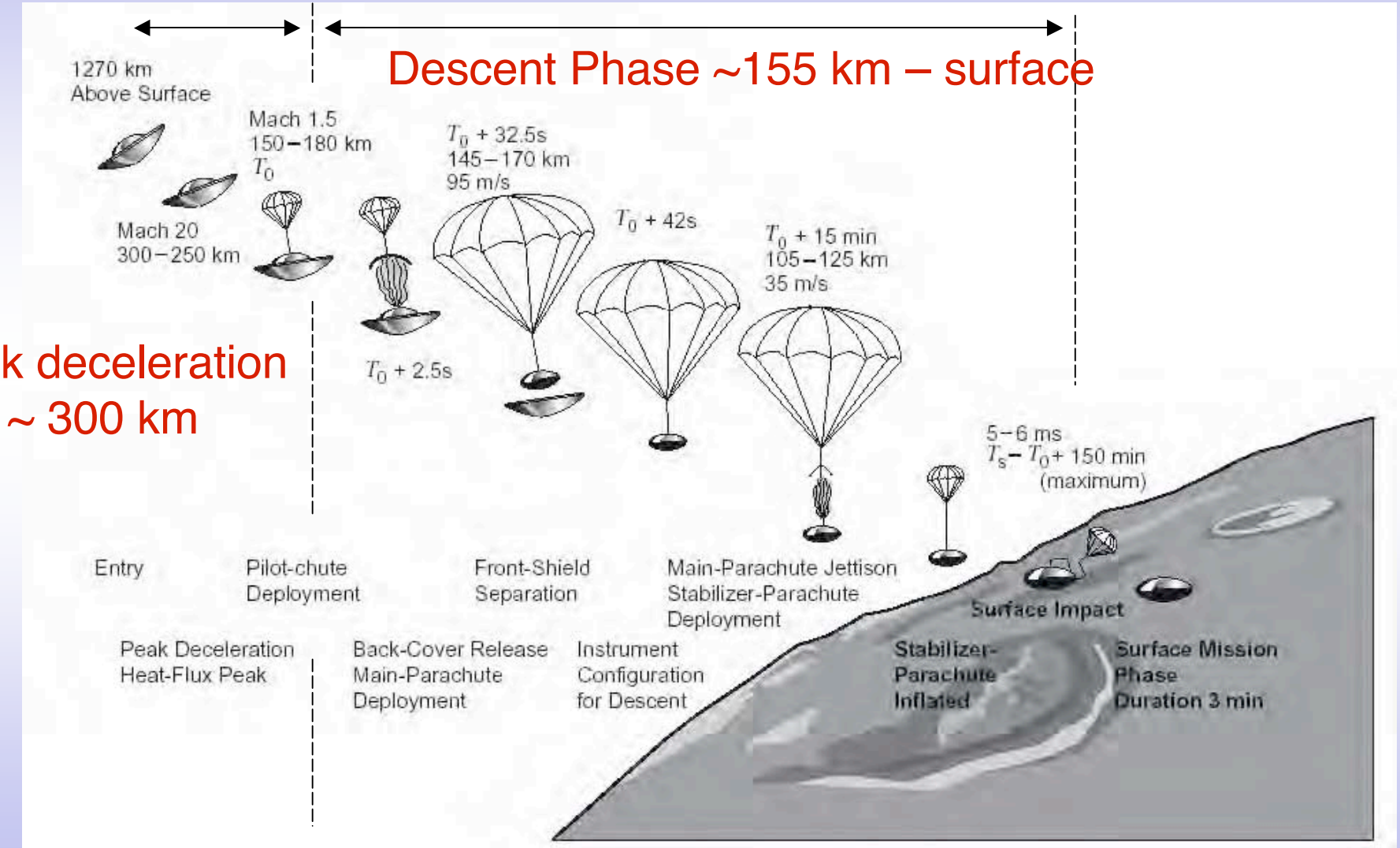
Team → Name → Acronym

→ Logo → T-shirt

Huygens Mission Sequence

~ 4 m 28 s

~ 2 h 27 m 50 s



Relevant Probe Measurments

Entry Phase:

- Atmospheric Structure Instrument (HASI): 3-axis acceleration
- Central and Radial Accelerometers: acceleration and spin

Descent Phase:

- Doppler Wind Experiment: probe longitude drift
- HASI: pressure and temperature, probe impact time
- Gas Chromatograph and Mass Spectrometer: mole fractions
- Surface Science Package: impact time
- Radar Altimeter Units: altitude and descent speed

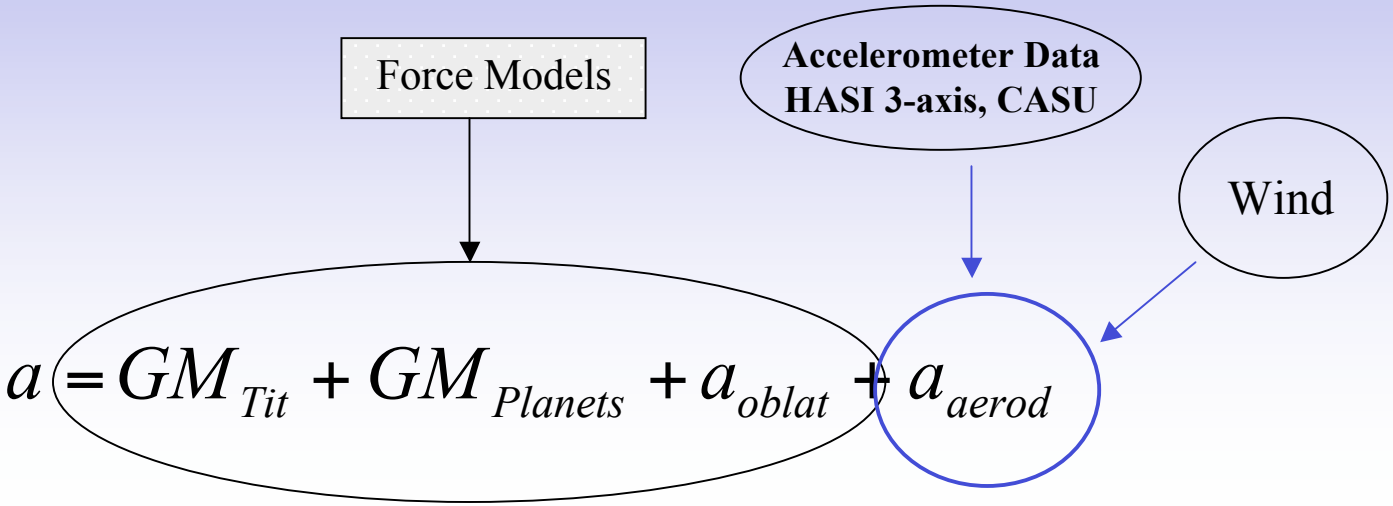
Reconstruction Stragey

Step 1: entry phase reconstruction (accelerometer data)

Step 2: descent phase reconstruction

Step 3: entry/descent phase merging (adjustment of IC)

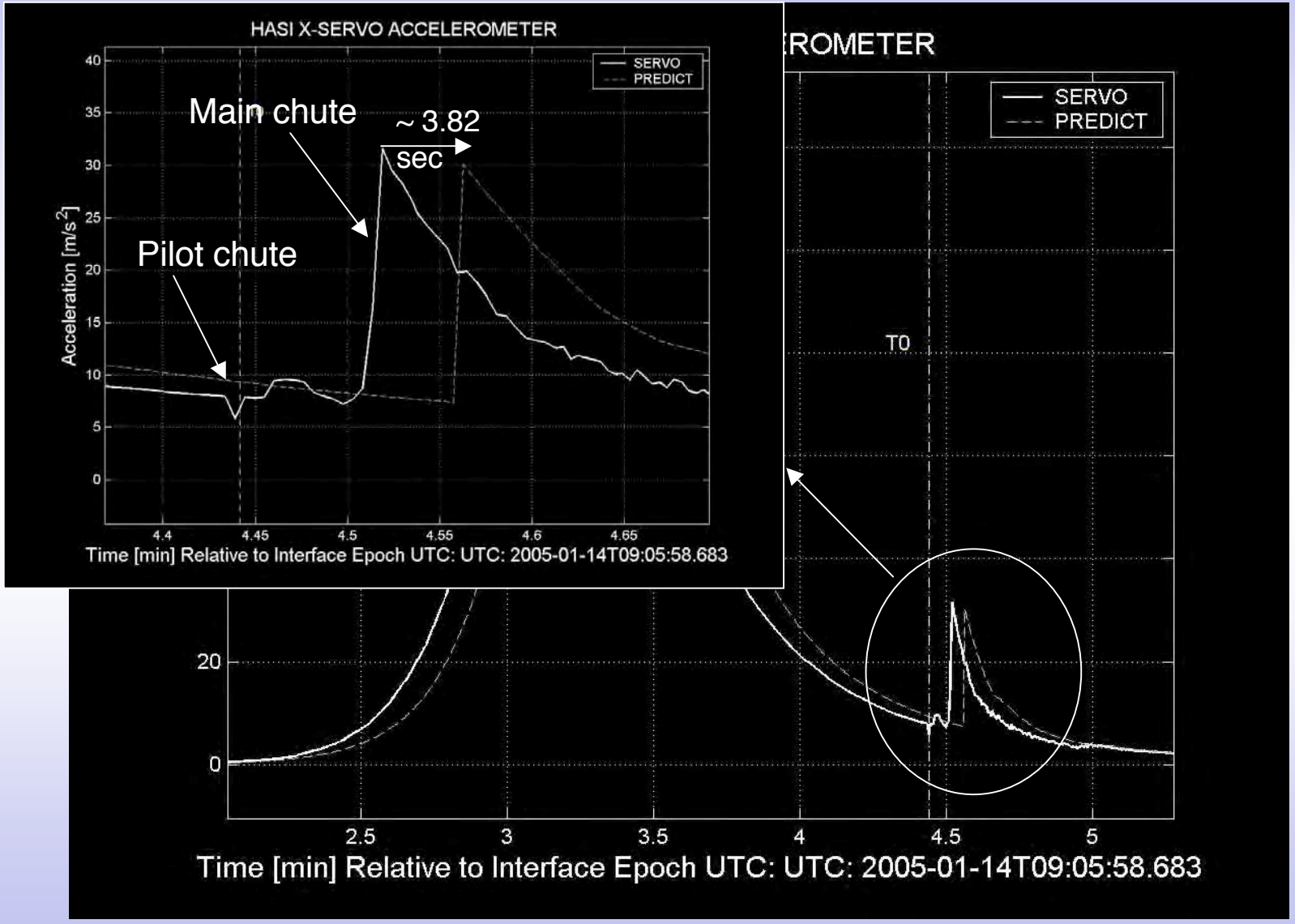
Entry Phase Reconstruction



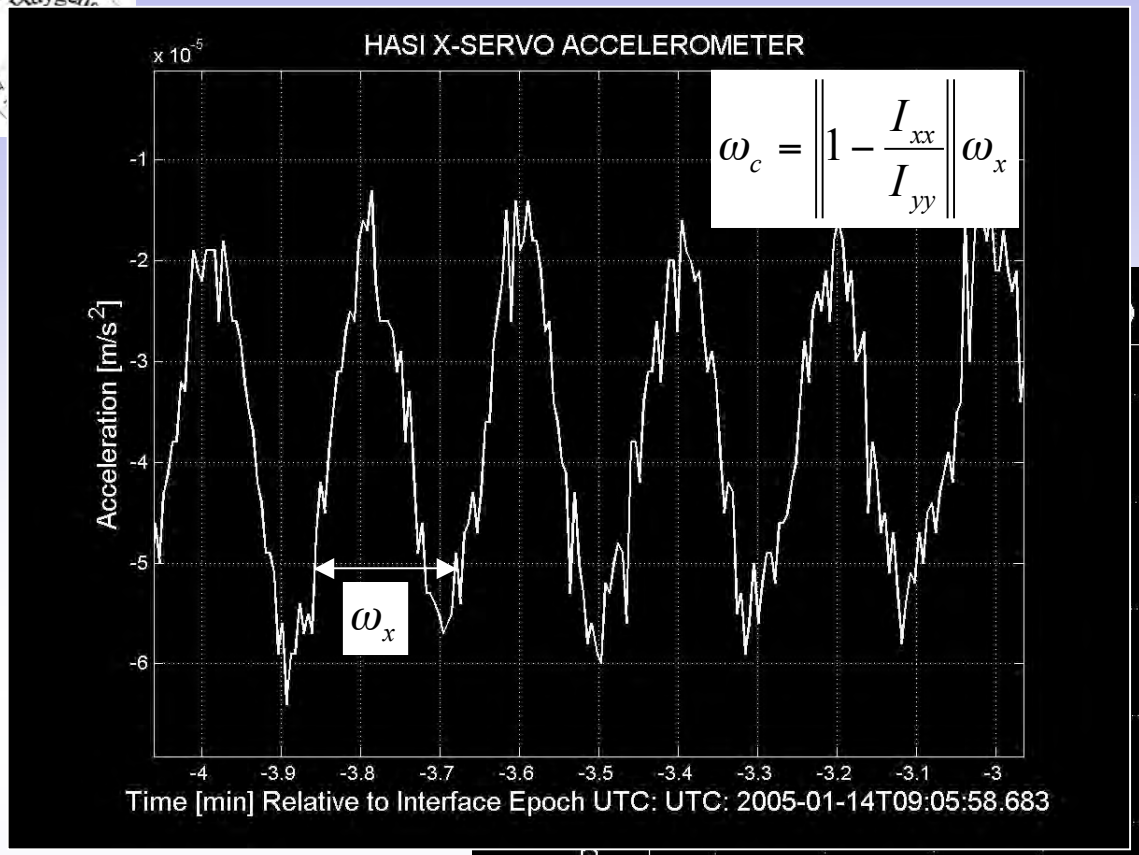
A requirement for the entry phase reconstruction is the consistency of:

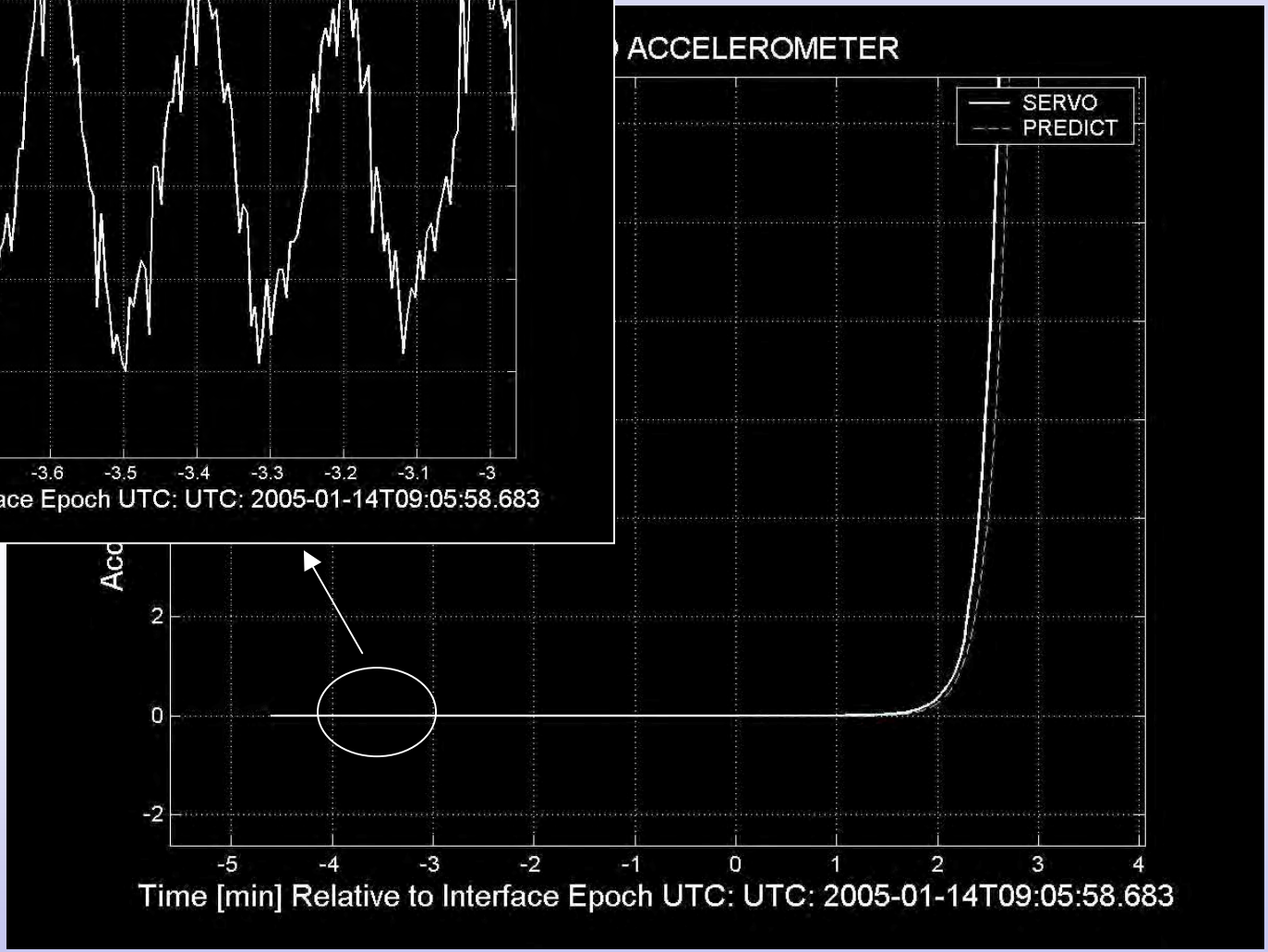
- The initial conditions and uncertainties;
- The measured probe deceleration (HASI 3-axis/CASU acc.);
- The descent phase trajectory;

Entry Phase: HASI-XSERVO Accelerometer



Coning Motion





~ 4.50 rpm

Reconstructed Entry Phase Altitude

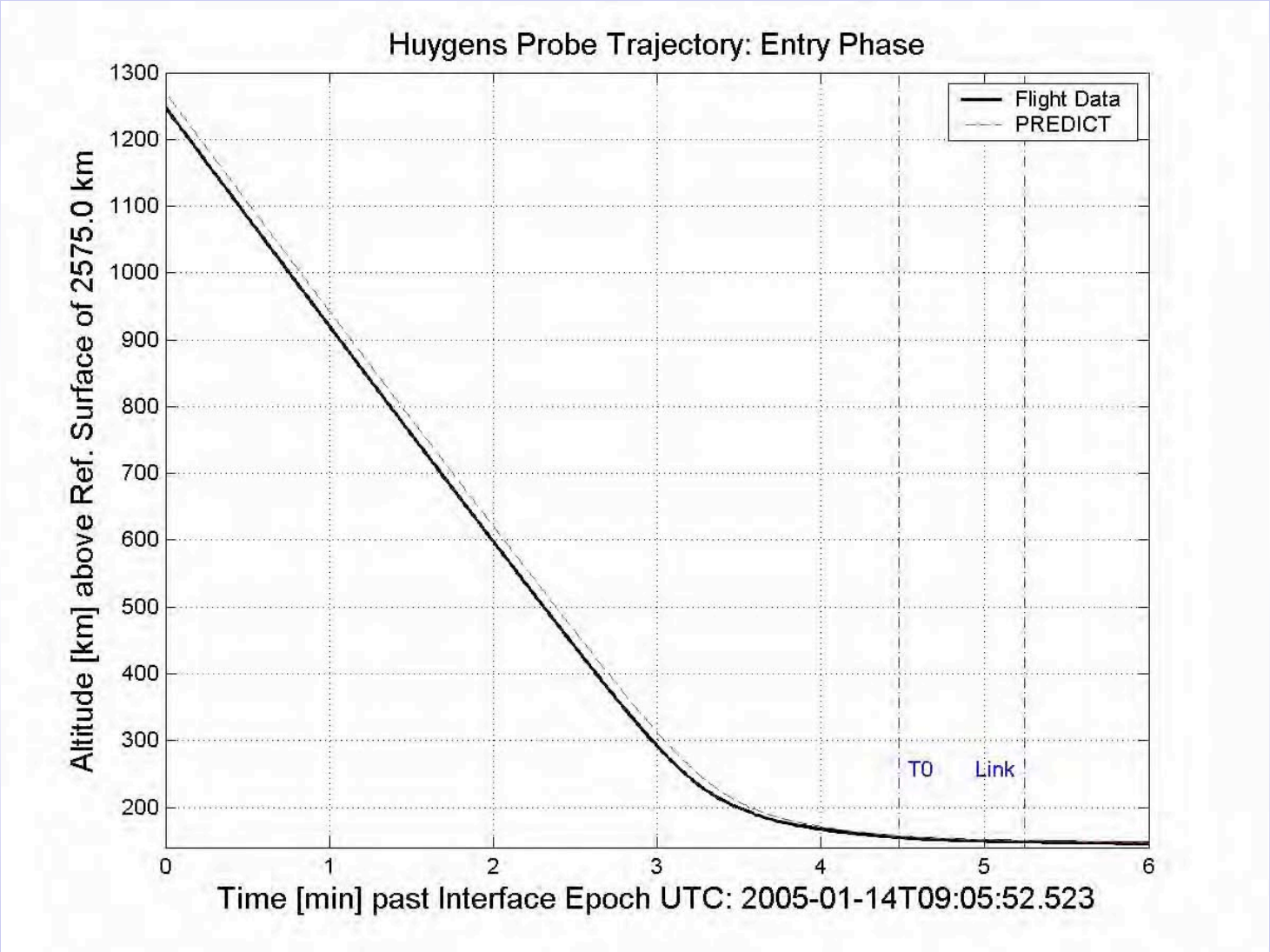
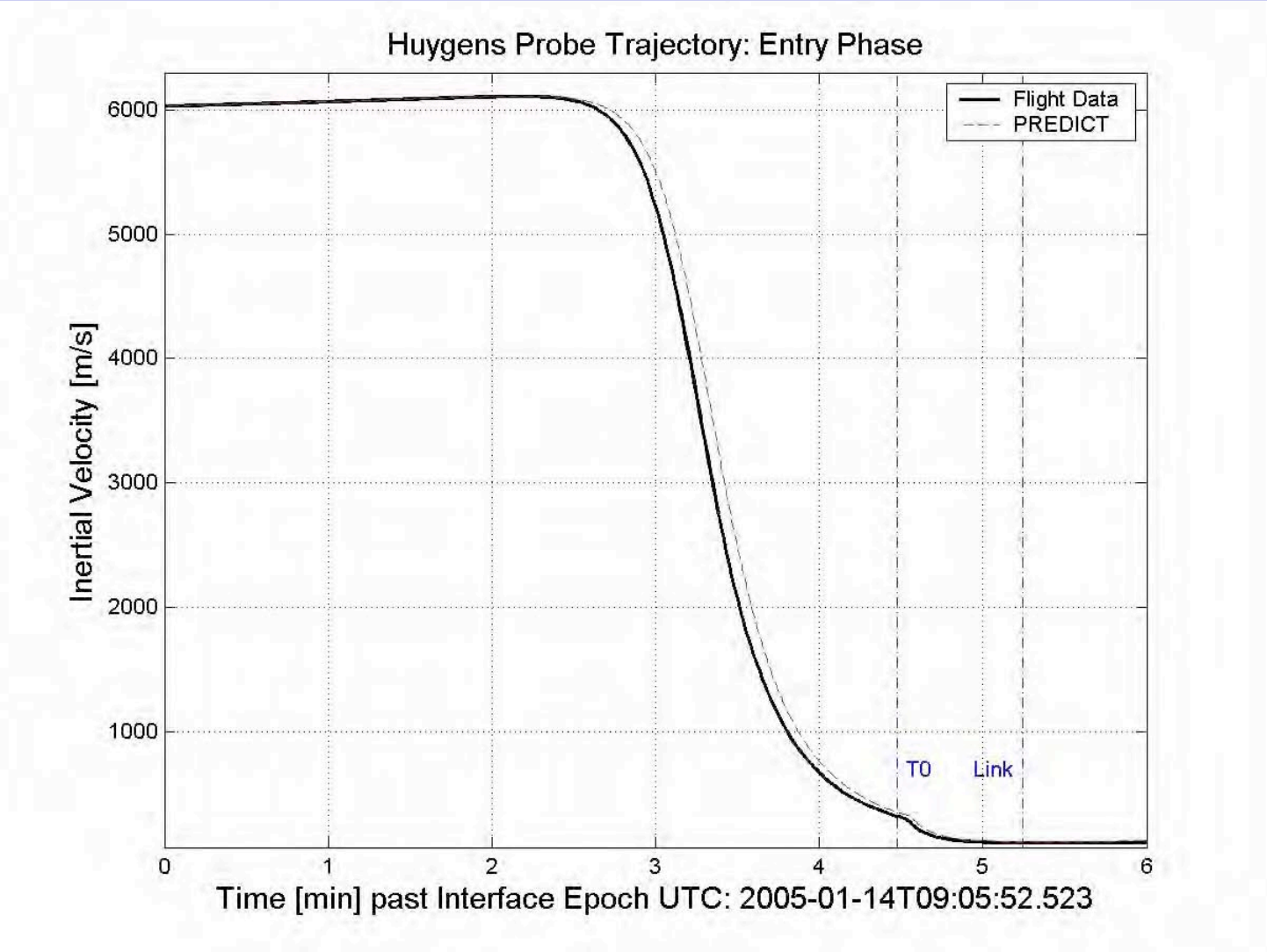


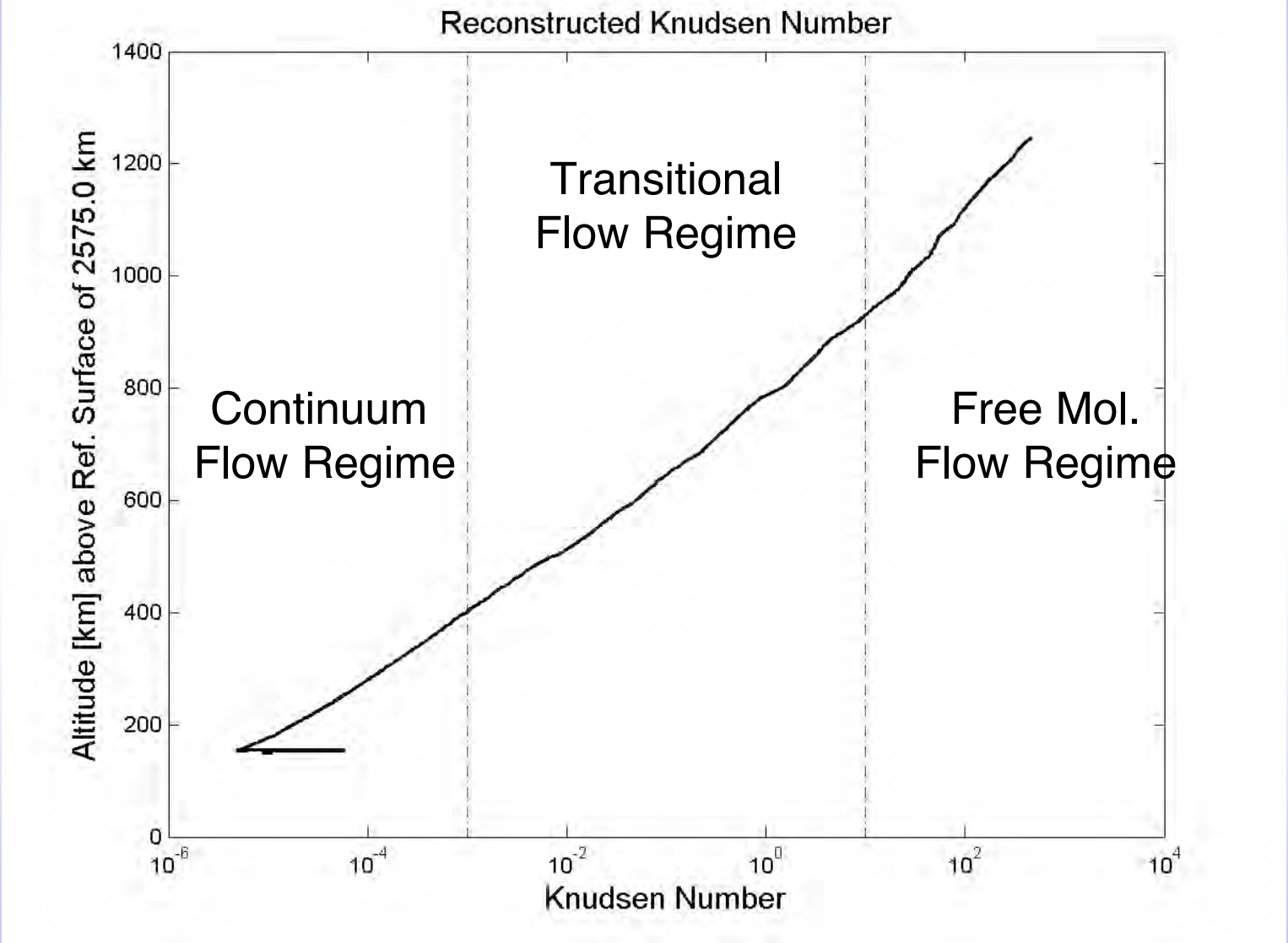
Table 1. Timing of important events in the probe mission timing sequence.[5,8] acc. = measured acceleration value; RE= rising edge of the deceleration profile; TE= trailing edge; T_A = triggering of the parachute sequence arming timer, S_0 = probe onboard software (POSW) mission timer start, T_0 = starting time of the parachute deployment sequence, and SCET = spacecraft event time. Note that RAU-1 and RAU-2 altitude measurements are actually available from 42 km and 38 km, respectively, even if the switch on time happened at an altitude of 62 km.

Phase	Time w.r.t. T_0	Event	SCET-UTC	Reconstructed Altitude
	T_0- 4 m 28 s	NASA/ESA Interface	09:05:53	1248 km
Entry phase	acc. $>$ 50 m/s^2 (RE)	S_0-detect. enabled		
	acc. $>$ 80 m/s^2 (RE)	T_A-detect. enabled		
	acc $<$ 10 m/s^2 (TE)	S_0-detect.		
	acc. $<$ 9.484 m/s^2 (TE)	T_A-detect.		
	$T_0 = S_0 + 6.375$ s	PDD firing	09:10:21	155 km
Descent with main chute and front shield	T_0+1.47 s	Pilot chute inflated		
	T_0+2.50 s	Back-cover release		
	T_0+4.95 s	Main parachute deployed		
	T_0+32.50 s	Front-shield jettison		
Descent with main chute	T_0+45.455 s	Probe relay link switch on	09:11:06	148 km
	T_0+900 s	Main parachute release	09:25:21	111 km
Descent with stabilizing drogue	T_0+901.02 s	Stabilizing drogue deployed		
	T_0+31 m 56 s	RAU power on	09:42:17	62 km
	T_0+ 2 h 27 m 50 s	Surface impact	11:38:11	0 km

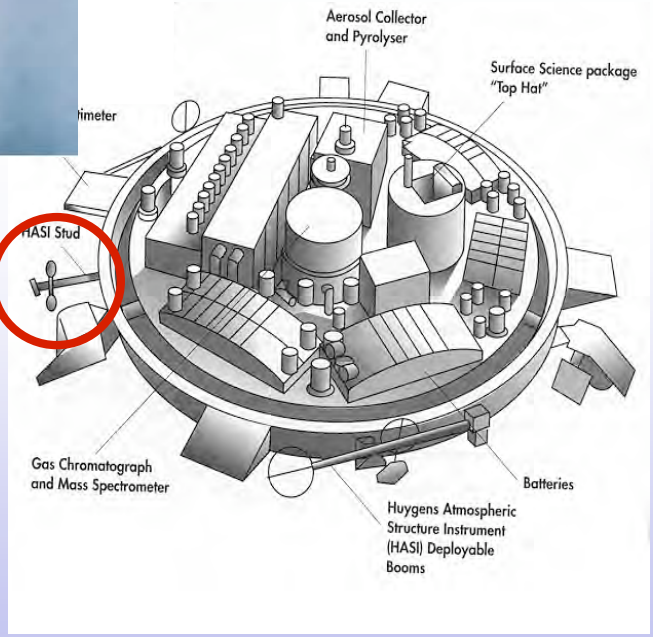
Reconstructed Entry Phase Inertial Vel.



Reconstructed Entry Phase Aerodynamics



Descent Phase Reconstruction



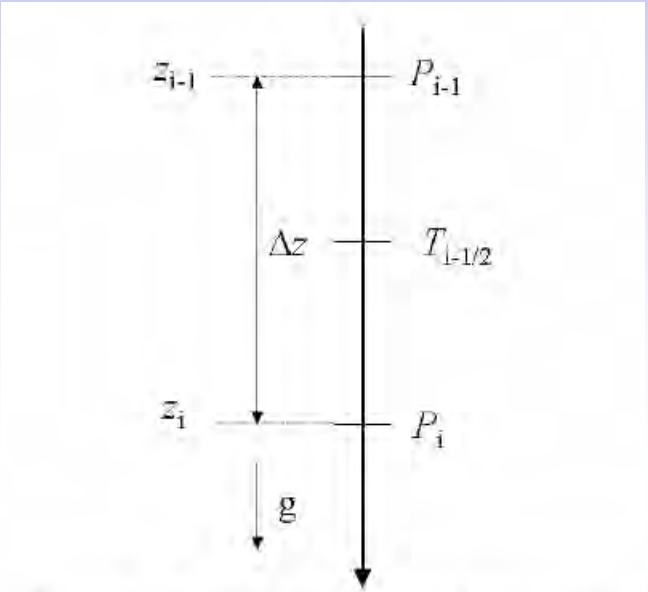
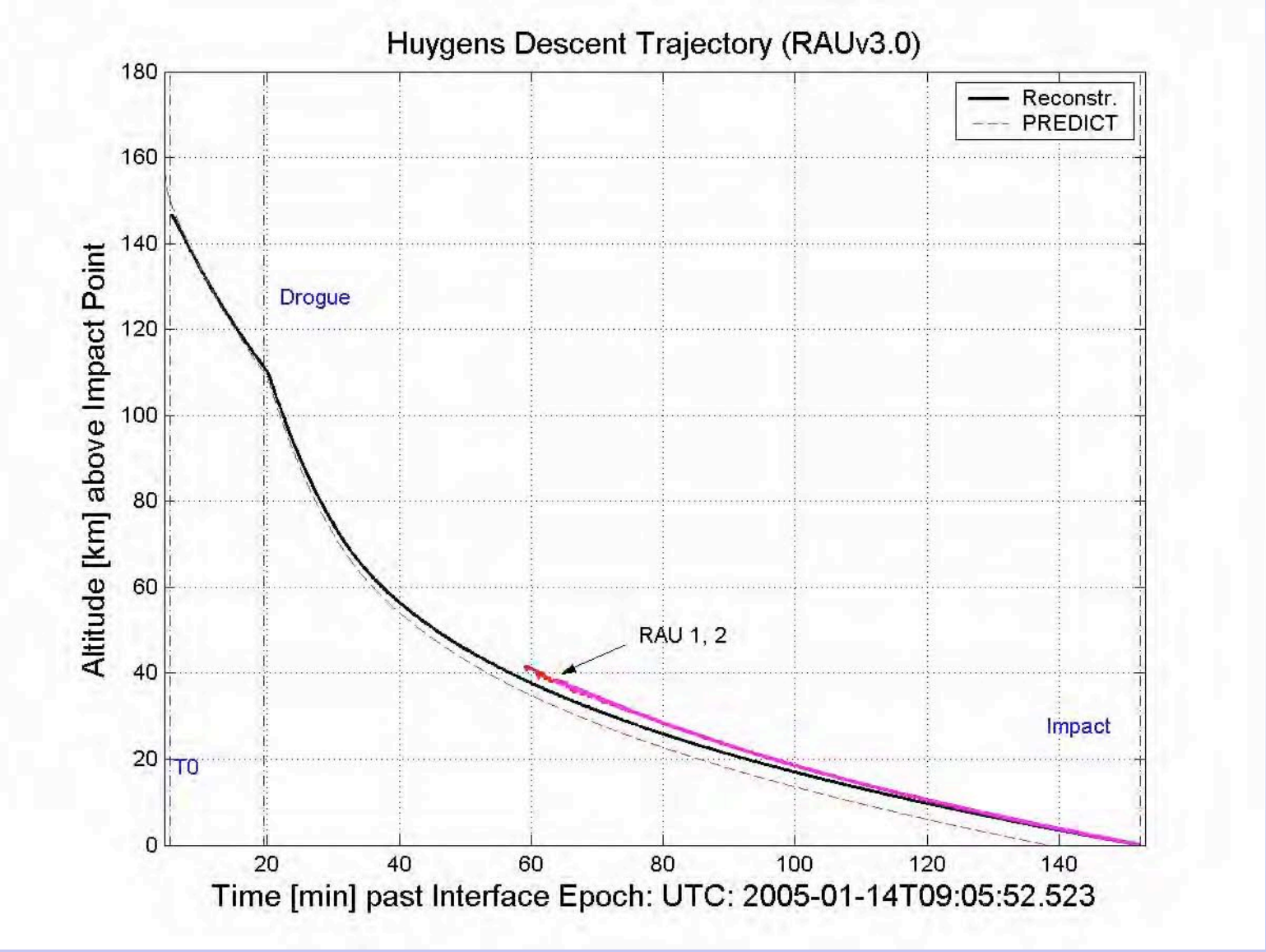


Figure 8.2: *Derivation of the descent altitude and speed from the measured atmospheric pressure gradient and temperature.*

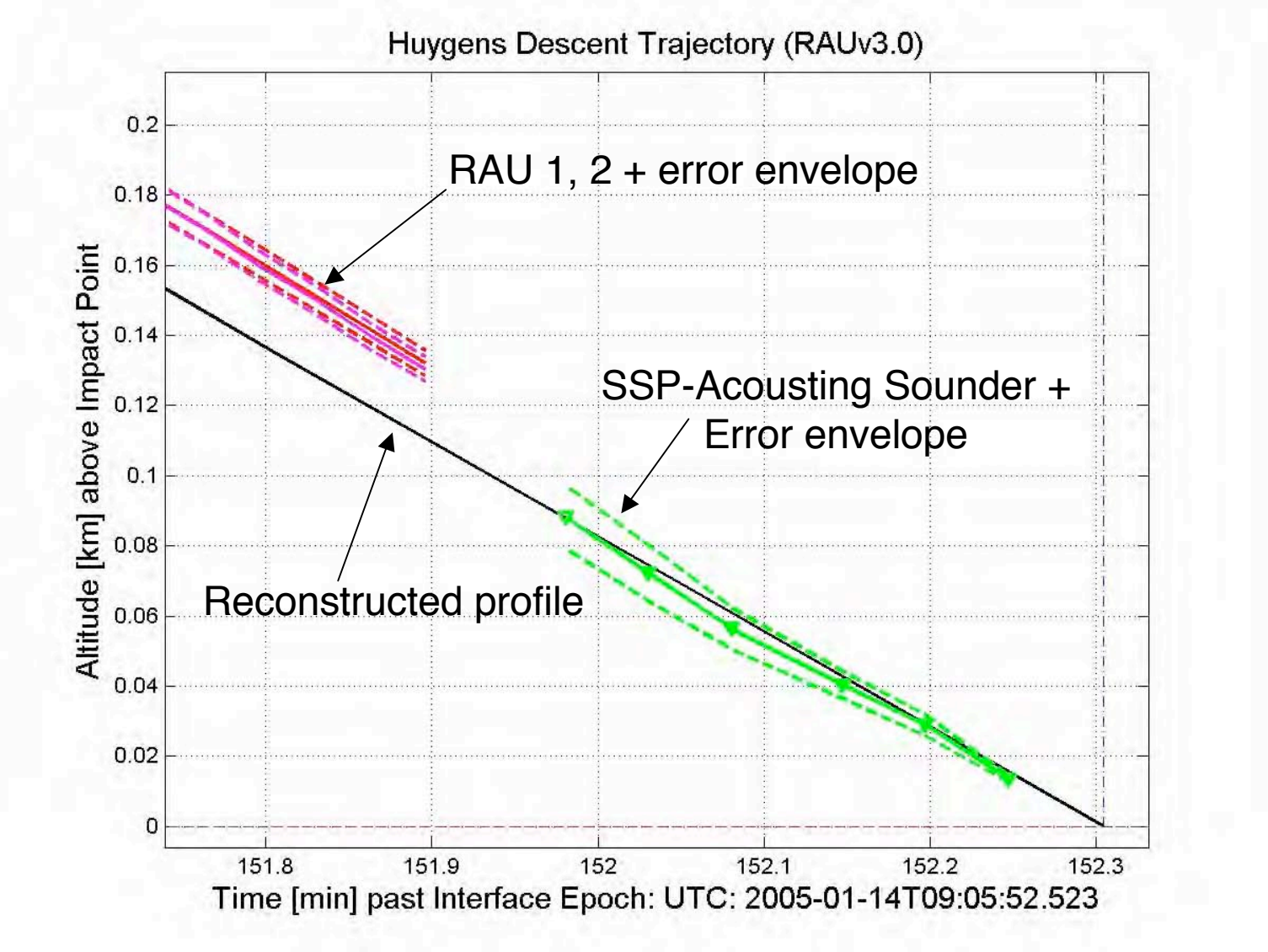
$$\Delta z = (z_i - z_{i-1}) = -\frac{1}{g}\frac{R T_{i-1/2}\,\zeta}{\mu}\ln\left(\frac{P_i}{P_{i-1}}\right)$$

$$z_i = z_0 + \sum_i \Delta z_{i-1}$$

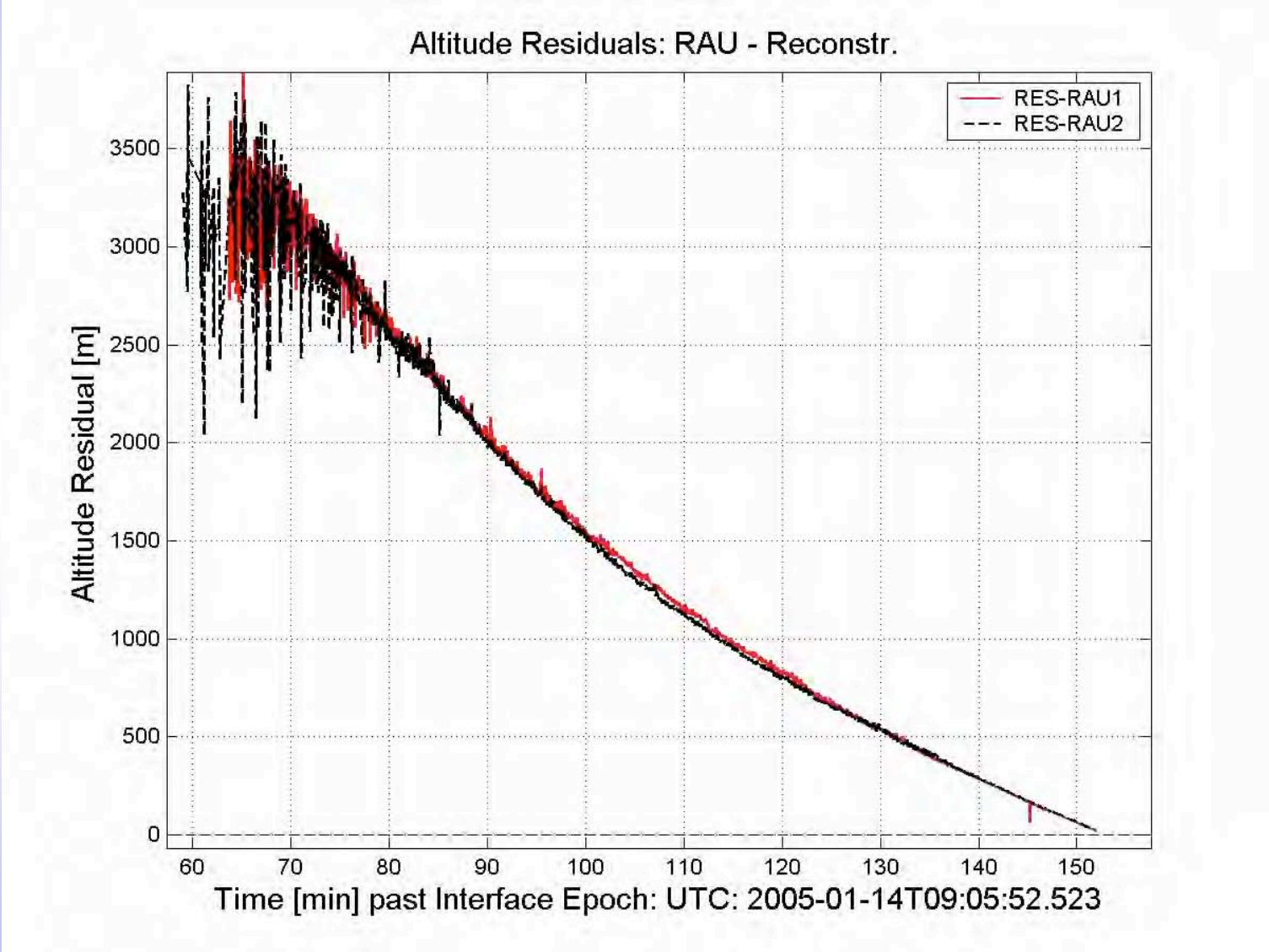
Descent Phase Altitude Profile



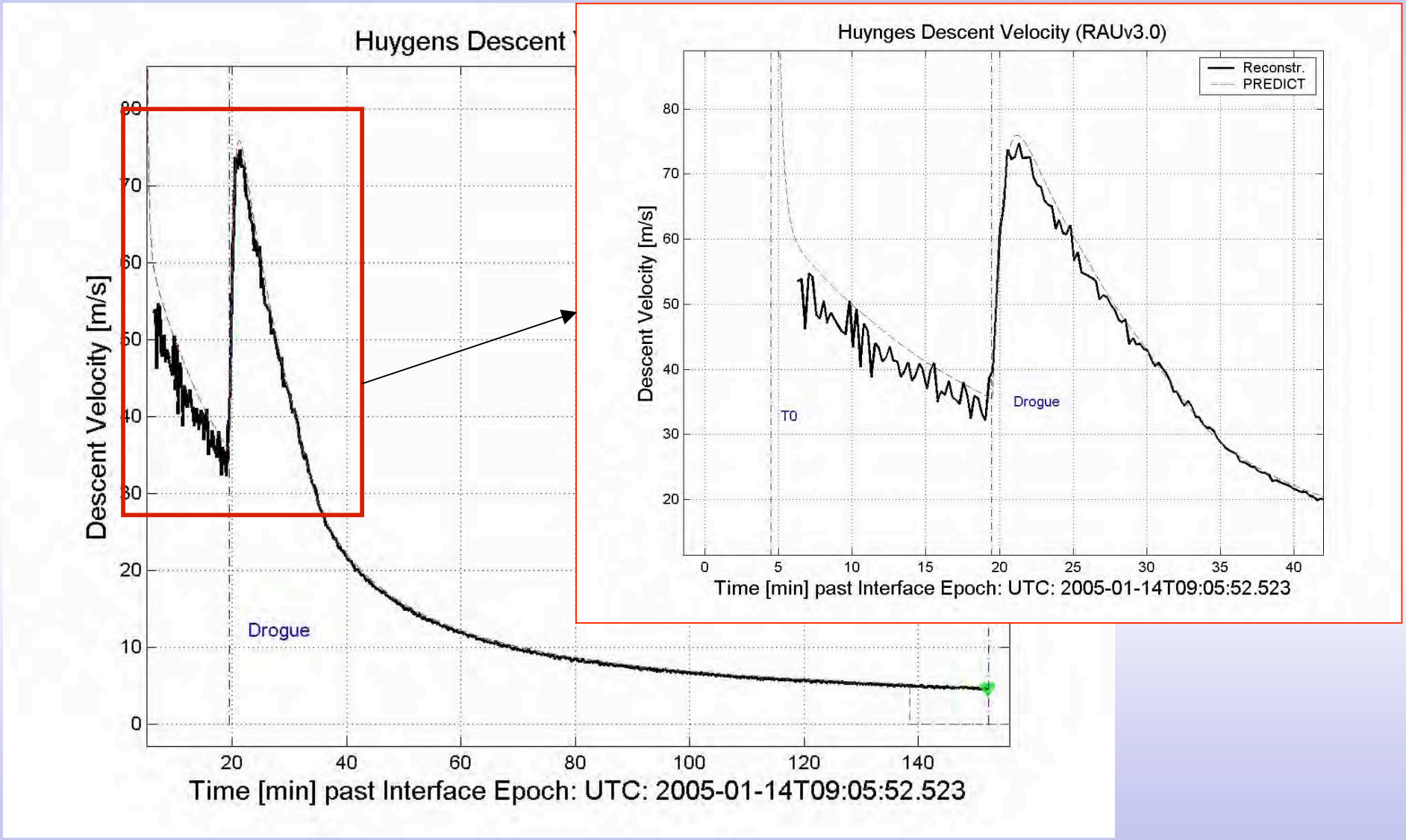
Descent Phase Altitude Profile

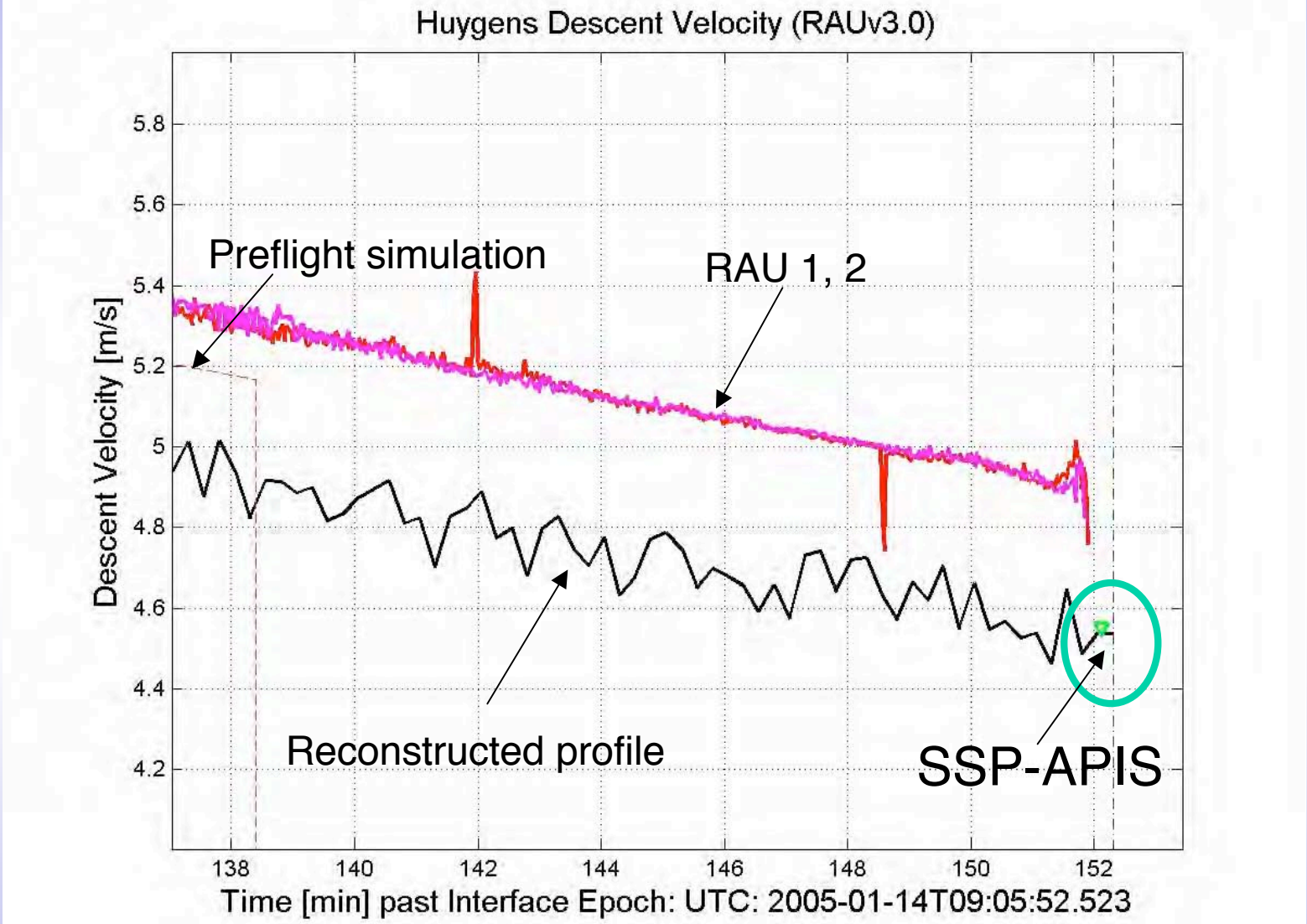


Descent Phase: Alt. Residuals to RAU

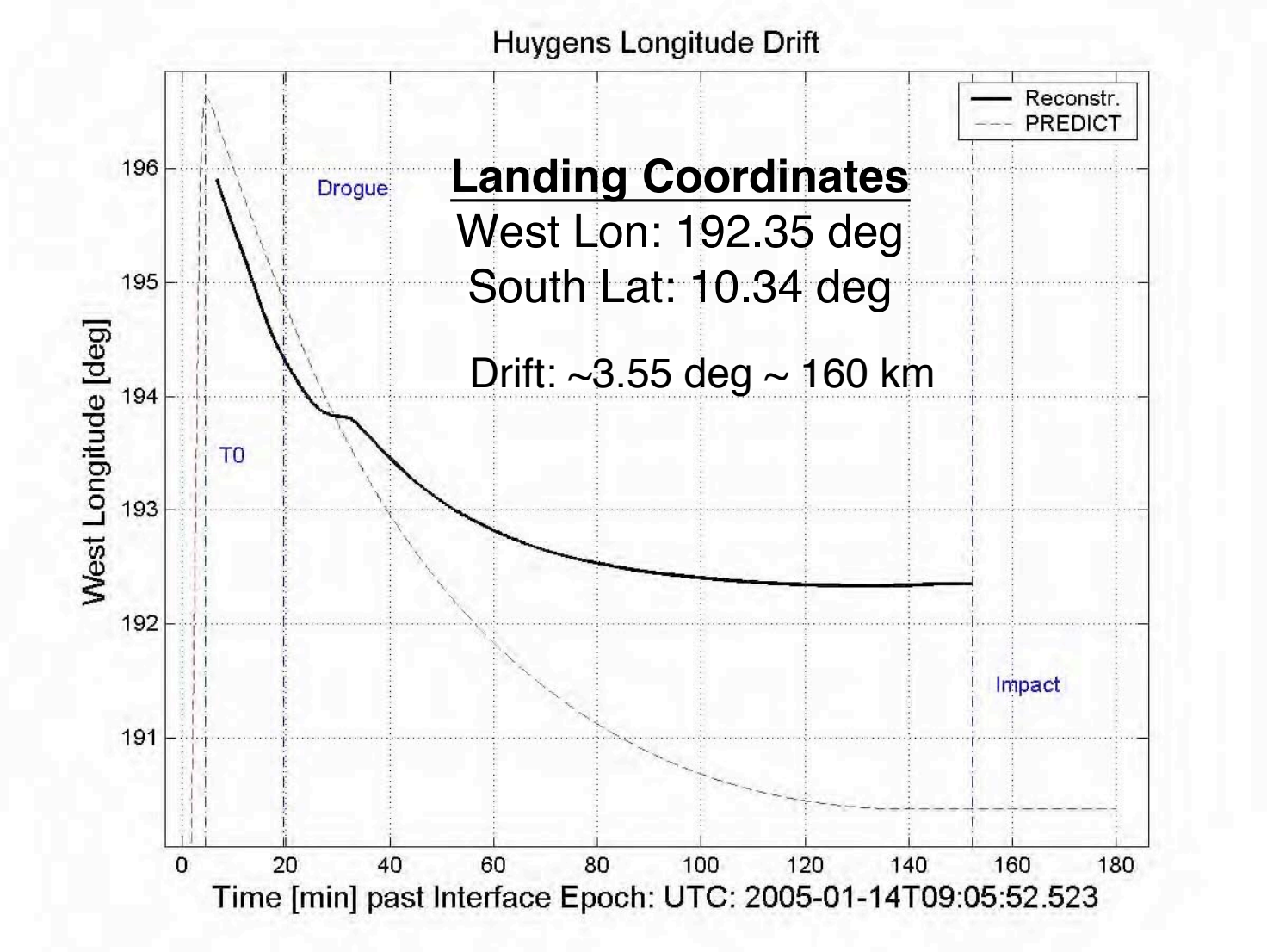


Descent Phase: descent speed profile

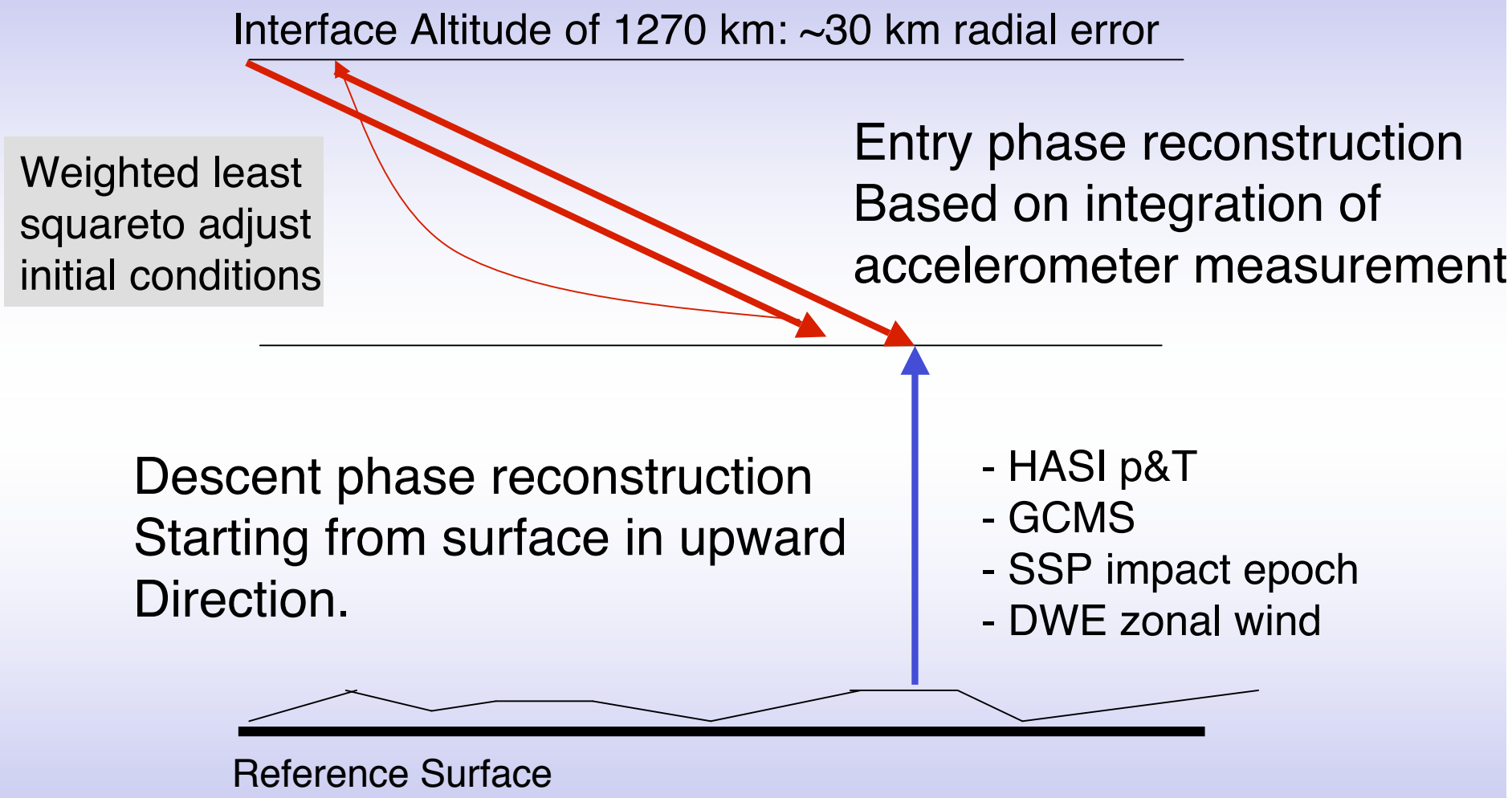



Huygens Descent Velocity (RAUv3.0)
Descent Velocity [m/s]
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
Preflight simulation
RAU 1, 2
Reconstructed profile
SSP-APIS
138
140
142
144
146
148
150
152
Time [min] past Interface Epoch: UTC: 2005-01-14T09:05:52.523

Reconstructed Longitude Drift (Descent)



Entry and Descent Phase Merging Strategy

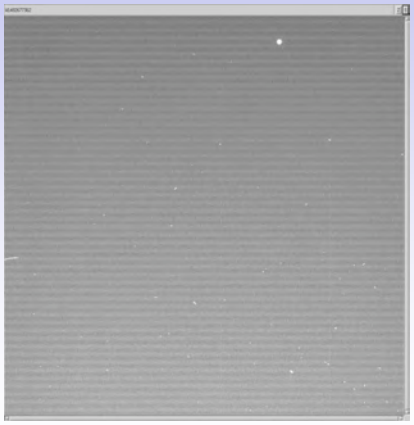


Adjustment of Initial State Vector

Table 2. Initial state vector at the epoch 2005-01-14T09:05:52.523 (UTC) as provided by the Cassini Navigation team (NAV column, JPL-050214 DELIVERY) with corresponding uncertainties and after the trajectory merging correction. The difference between the NAV vector and the adjusted one is provided in the last column in units of the NAV 1σ uncertainty. Reference system for cartesian coordinates: Titan centered EME2000 with units in km and km/s.

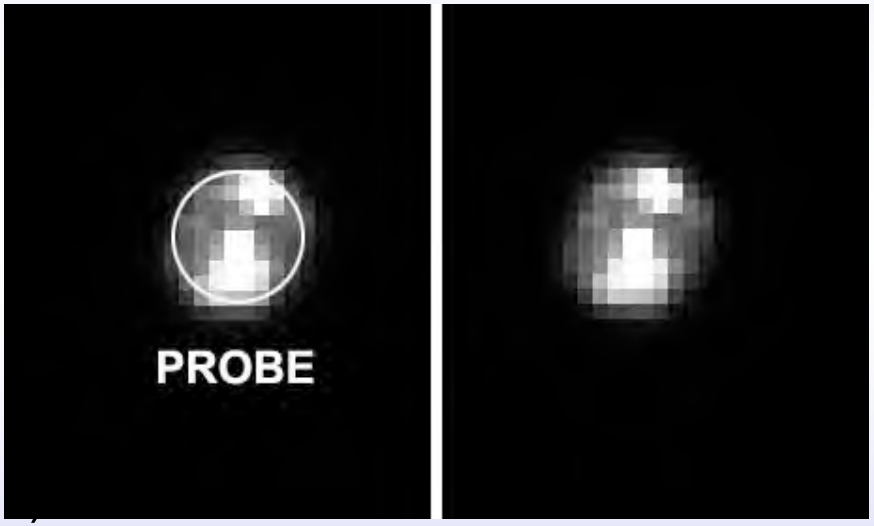
Coordinate	NAV	1σ	Adjusted	Difference $[\sigma]$
x	-74.84856340	5.618650402E+00	-68.24626095	-1.18
y	-3832.088332	3.209952528E+01	-3809.336798	-0.71
z	-305.9503431	3.634049423E+00	-311.8217596	1.62
vx	-2.379991142	8.584831270E-04	-2.379411383	-0.68
vy	5.537146584	3.231745036E-03	5.534426806	0.84
vz	0.2269144660	4.460877926E-04	0.2273084312	-0.88
WLon	185.53	0.127	185.43	0.79
SLat	8.50	0.115	8.61	-0.96
Altitude	1270.01	30.73	1247.69	0.73

Huygens Probe Imaging by Cassini



Huygens on Christmas day

Probe Release: 25 December 2005



Huygens on December 27 in the NAC

Imaging Opportunities

Release + 1 day: WAC (10 pixels)

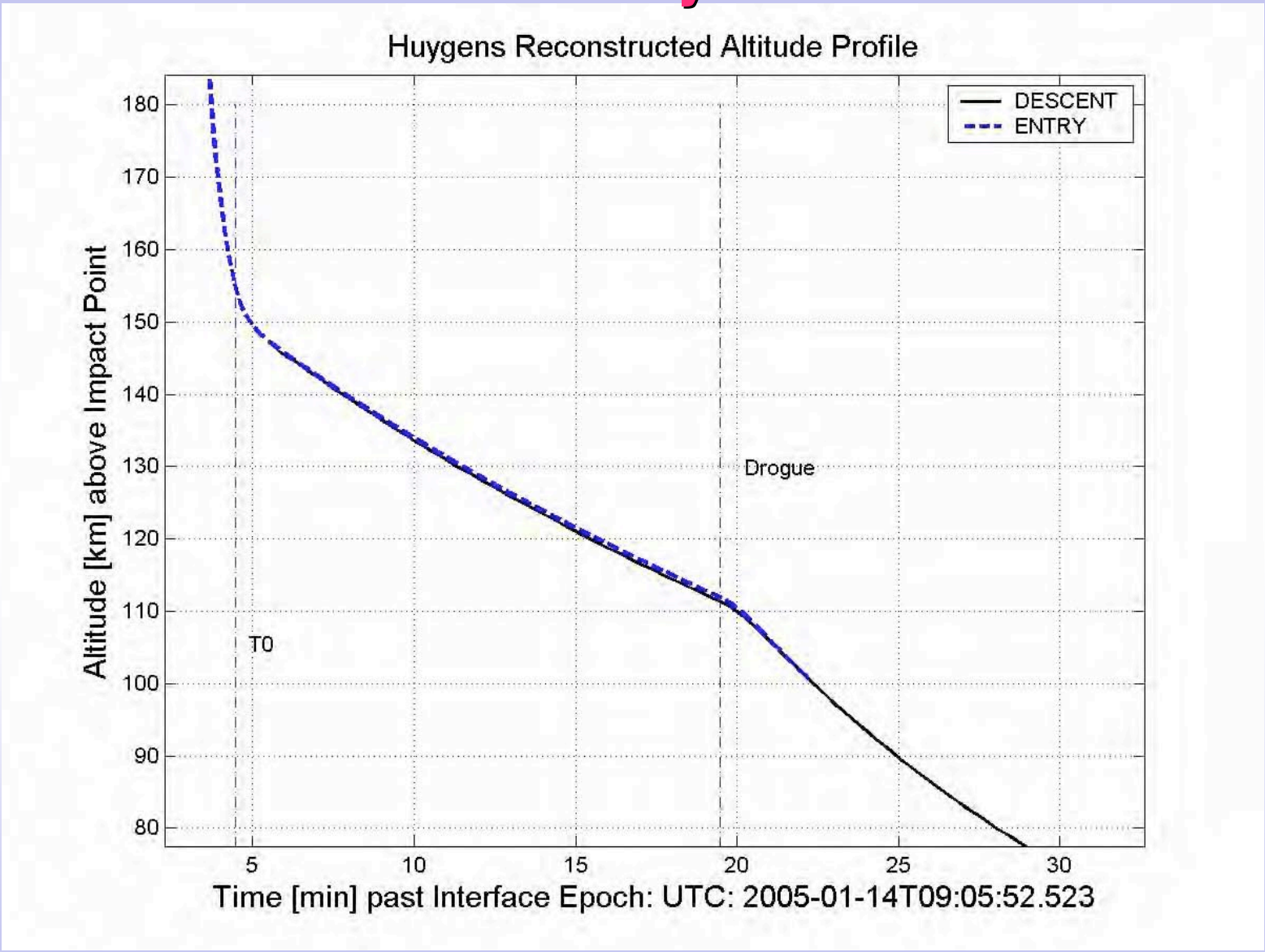
Release + 2 days: WAC/NAC (5/50 pixel

Release + 3 days: WAC/NAC (2/20 pixel

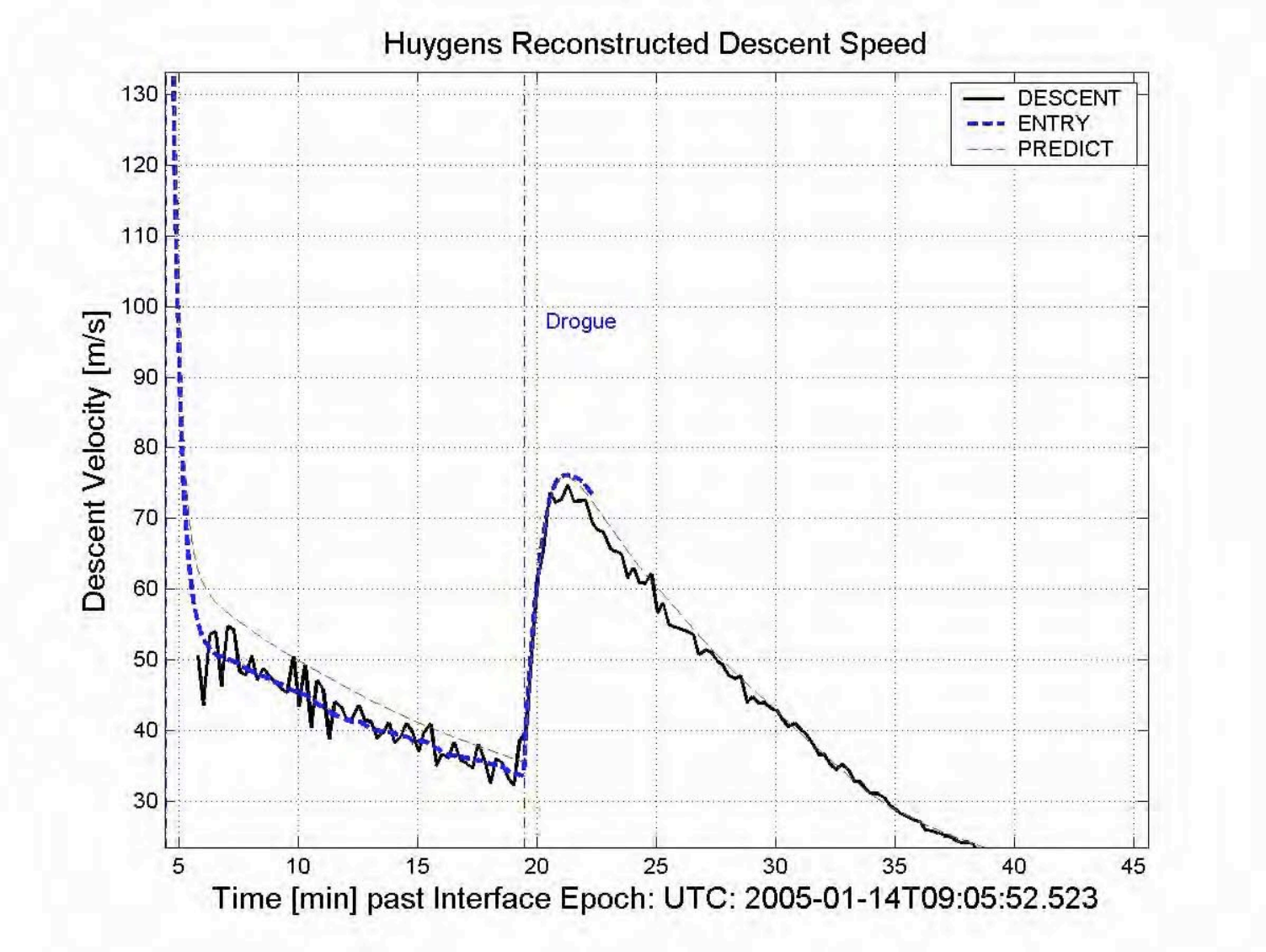
Benefit of Imaging

Optical Navigation techniques was used to reduce the size of the probe entry interface delivery ellipse at 1270 km altitude !

Altitude Profiles: Entry + Descent Phase



Descent Speed: Entry + Descent Phase



Summary and Future Work

- The Huygens scientific and housekeeping data sets are of high quality and allowed to reconstruct the probe entry and descent trajectory (altitude, descent speed, longitude drift, etc.)
- There are still some inconsistencies between the atmospheric derived descent trajectory and the Radar Altimeter Units. The F raw data calibration is still not finalized and will most probably further reduce this gap (internal probe temperature modeling).
- The VLBI observations will provide an independent reconstructe descent trajectory. This trajectory (given w.r.t. celestial referenc frame) will be transformed into a Titan centered reference syste and will then provide an additional means to verify the reconstruction effort.

More Literature on this Subject

„ *Methodology Development for the Reconstruction of the ESA Huygens Probe Entry and Descent Trajectory*

PhD Dissertation, Bobby Kazeminejad

Karl-Franzens University Graz, Austria
March 2005

http://huygens.oeaw.ac.at/DTWGPapers.html