The Huygens Mission to Titan: Overview and status

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Cassini Project, Jet Propulsion Laboratory, Pasadena, USA

Cassini-Huygens
A 3-agency International Mission
NASA, ESA, ASI
19 countries involved

Christiaan Huygens

Giovanni Domenico Cassini

esa
european space agency
agence spatiale européenne

NASA
National Aeronautics
Space Administration

CASSINI SCIENCE OBJECTIVES

MAGNETOSPHERE

1. CONFIGURATION AND CURRENT SYSTEMS
2. PARTICLE COMPOSITION, SOURCES AND SINKS
3. DYNAMICS OF THE MAGNETOSPHERE
4. INTERACTION WITH SOLAR WIND, SATELLITES AND RINGS
5. TITAN'S INTERACTION WITH SOLAR WIND AND MAGNETOSPHERE

SOLAR WIND

SATURN

1. CLOUD PROPERTIES/ATMOSPHERIC COMPOSITION
2. WINDS AND TEMPERATURES
3. INTERNAL STRUCTURE AND ROTATION
4. SATURN'S IONOSPHERE
5. ORIGIN AND EVOLUTION OF SATURN

RINGS

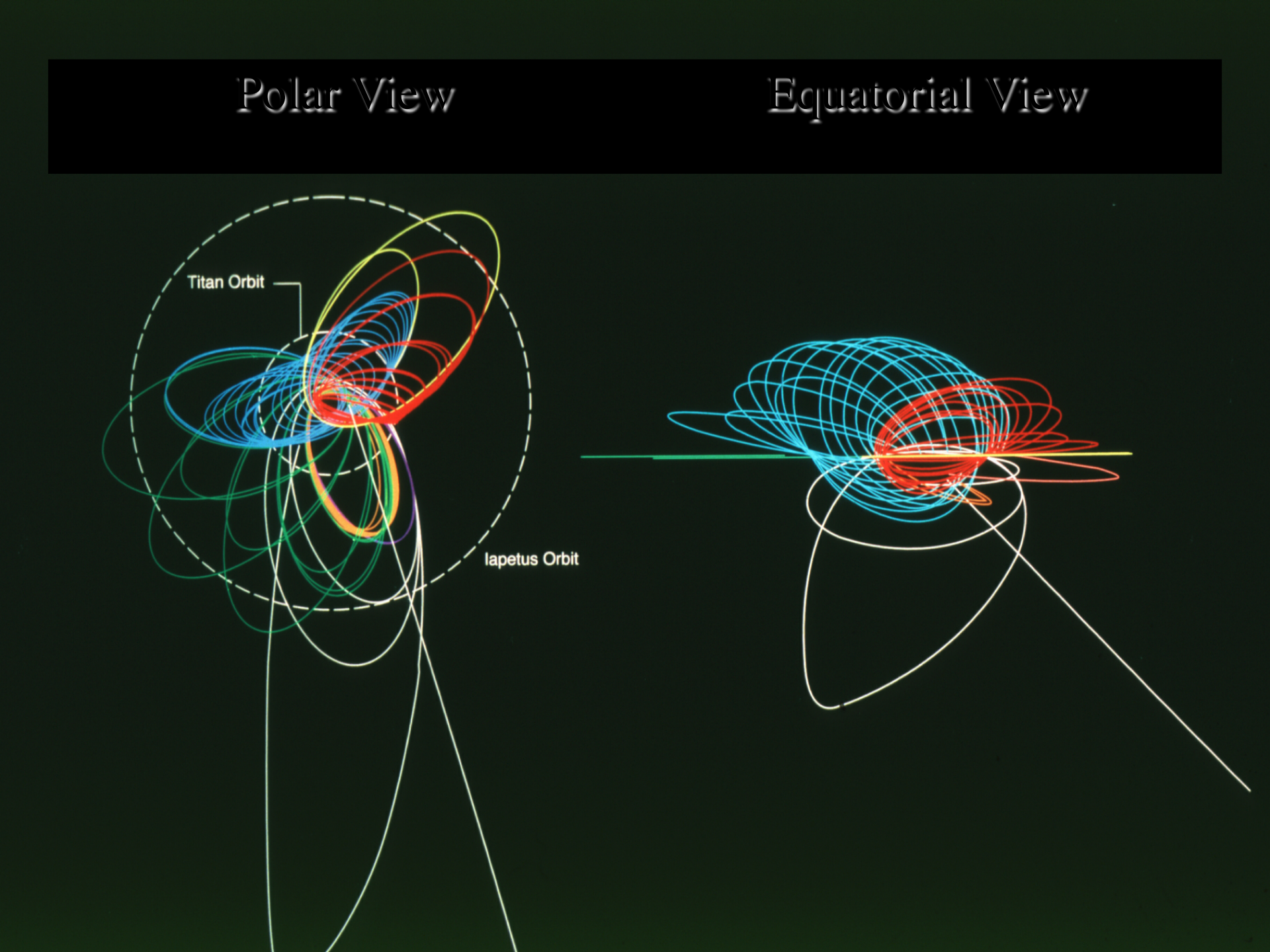
1. STRUCTURE AND COMPOSITION
2. DYNAMICAL PROCESSES
3. INTERRELATION OF RINGS AND SATELLITES
4. DUST/MICROMETEOROID ENVIRONMENT

TITAN

1. ATMOSPHERIC CONSTITUENT ABUNDANCES
2. DISTRIBUTIONS OF TRACE GASES AND AEROSOLS
3. WINDS AND TEMPERATURES
4. SURFACE STATE AND COMPOSITION
5. UPPER ATMOSPHERE

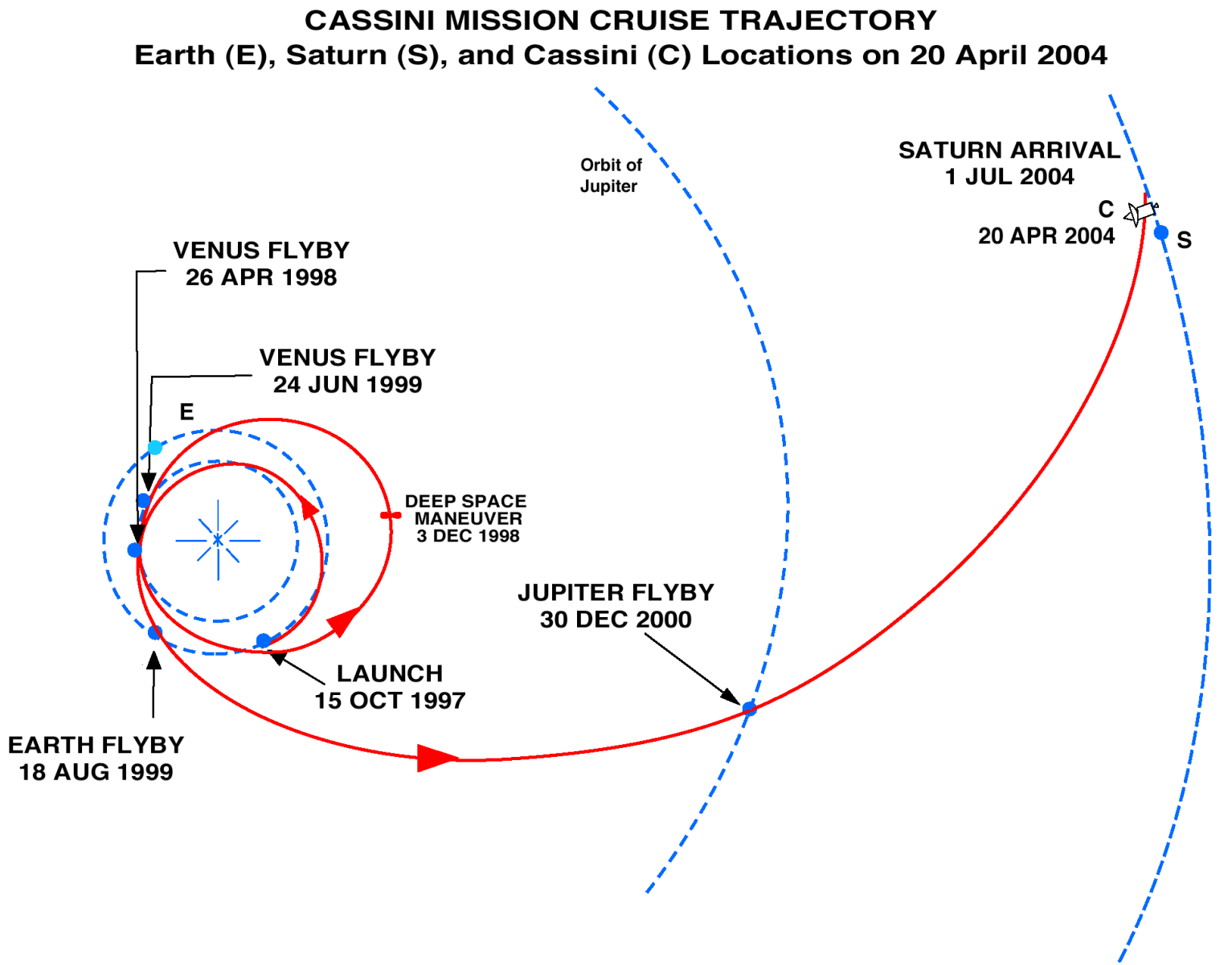
ICY SATELLITES

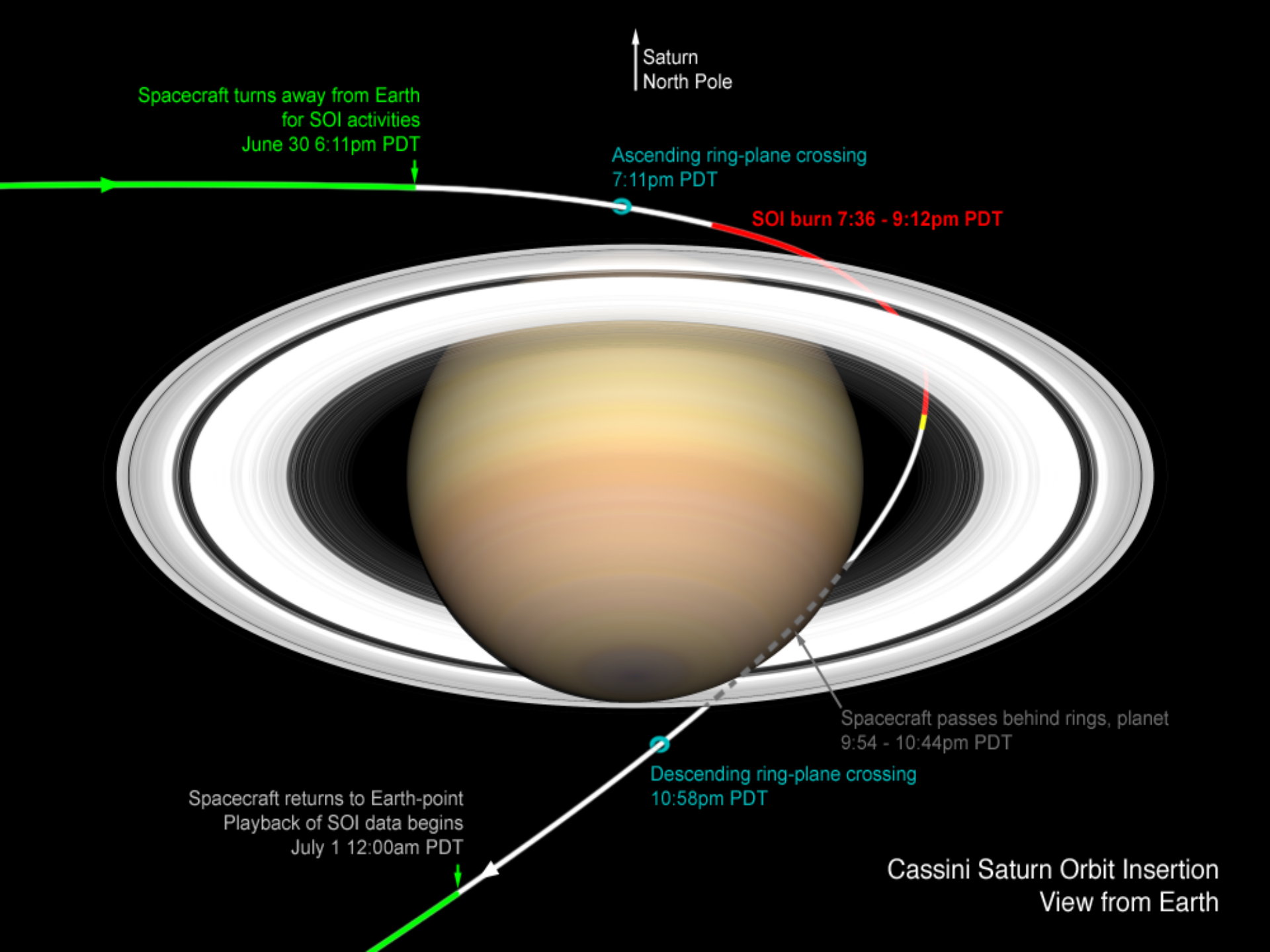
1. CHARACTERISTICS AND GEOLOGICAL HISTORIES
2. MECHANISMS OF SURFACE MODIFICATION
3. SURFACE COMPOSITION AND DISTRIBUTION
4. BULK COMPOSITION AND INTERNAL STRUCTURE
5. INTERACTION WITH MAGNETOSPHERE


Polar View
Equatorial View
Titan Orbit
Iapetus Orbit

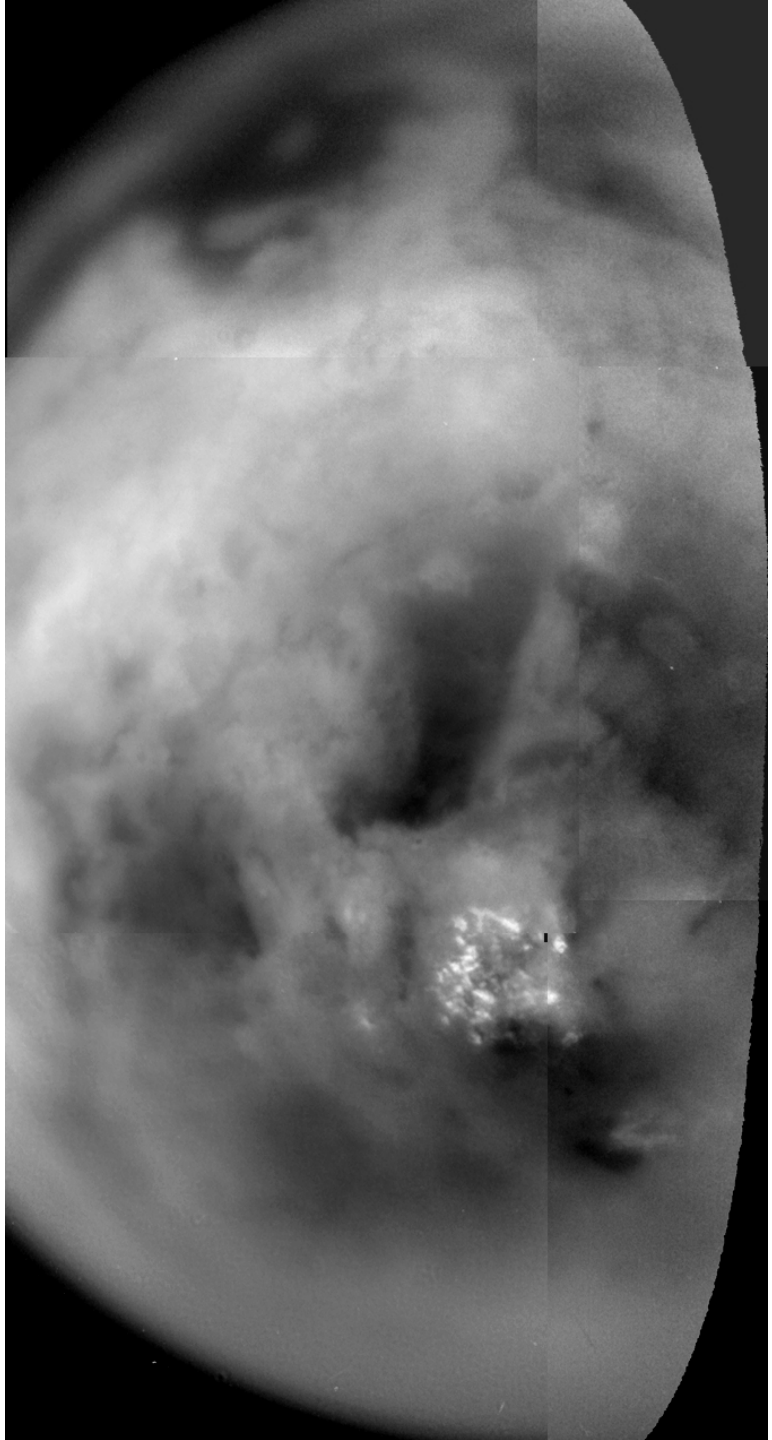
CASSINI
MISSION TO SATURN
CASSINI

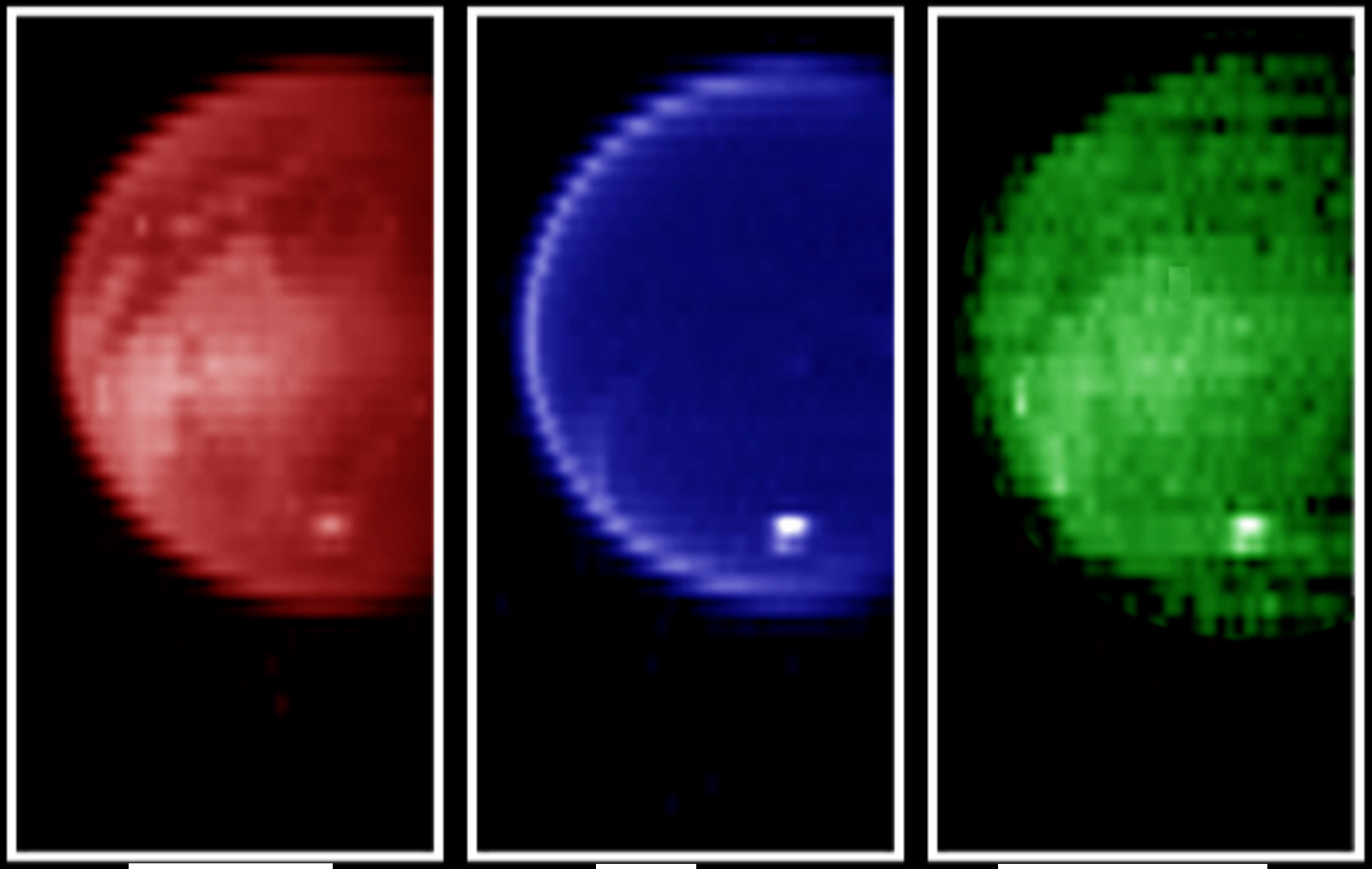
October 15, 1997
Launched from K.S.C.


CASSINI MISSION CRUISE TRAJECTORY
Earth (E), Saturn (S), and Cassini (C) Locations on 20 April 2004
Orbit of Jupiter
SATURN ARRIVAL 1 JUL 2004
C
20 APR 2004
S
VENUS FLYBY 26 APR 1998
VENUS FLYBY 24 JUN 1999
E
DEEP SPACE MANEUVER 3 DEC 1998
JUPITER FLYBY 30 DEC 2000
LAUNCH 15 OCT 1997
EARTH FLYBY 18 AUG 1999


Saturn
North Pole
Spacecraft turns away from Earth
for SOI activities
June 30 6:11pm PDT
Ascending ring-plane crossing
7:11pm PDT
SOI burn 7:36 - 9:12pm PDT
Spacecraft passes behind rings, planet
9:54 - 10:44pm PDT
Descending ring-plane crossing
10:58pm PDT
Spacecraft returns to Earth-point
Playback of SOI data begins
July 1 12:00am PDT
Cassini Saturn Orbit Insertion
View from Earth

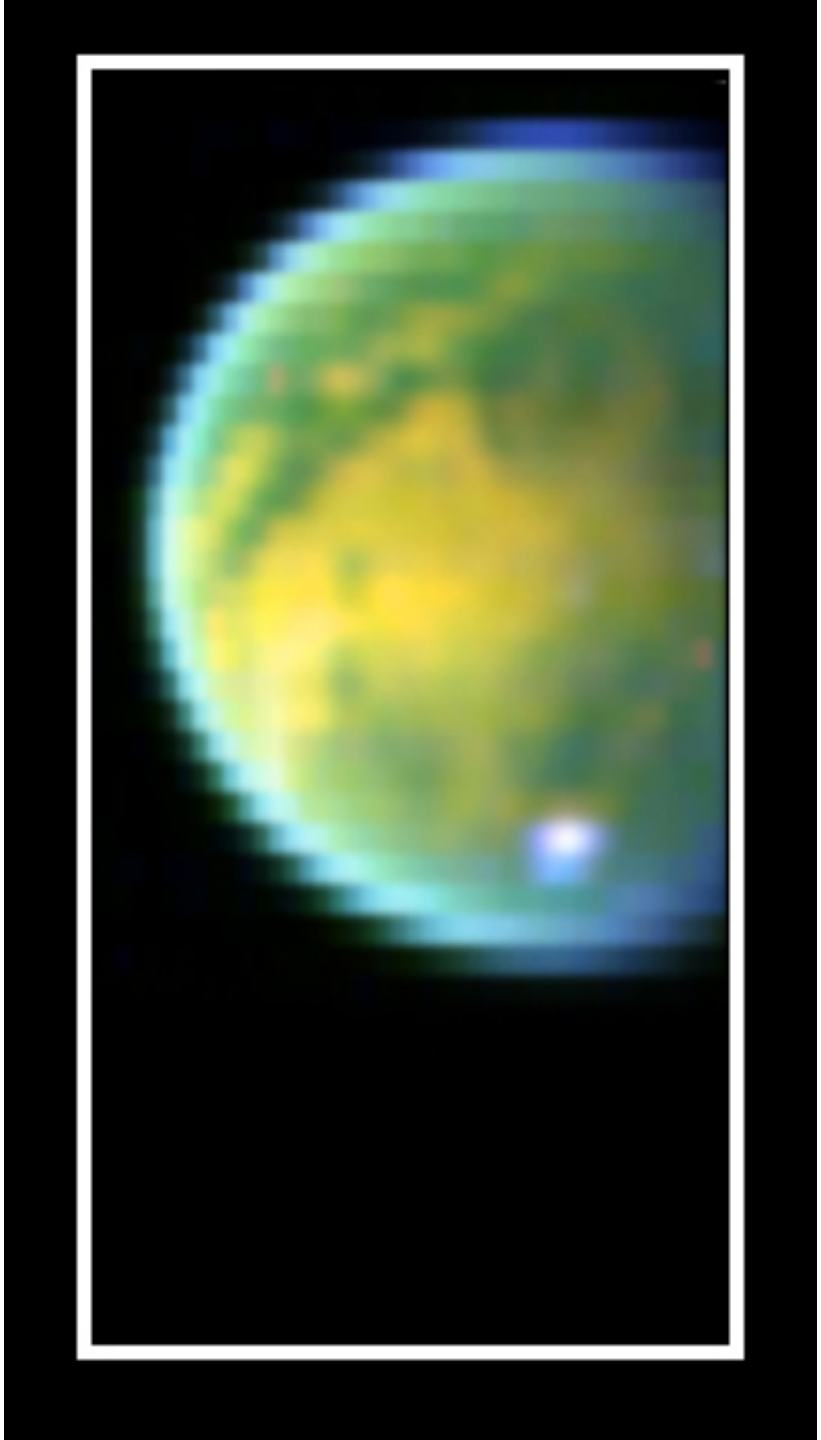
Cassini ISS

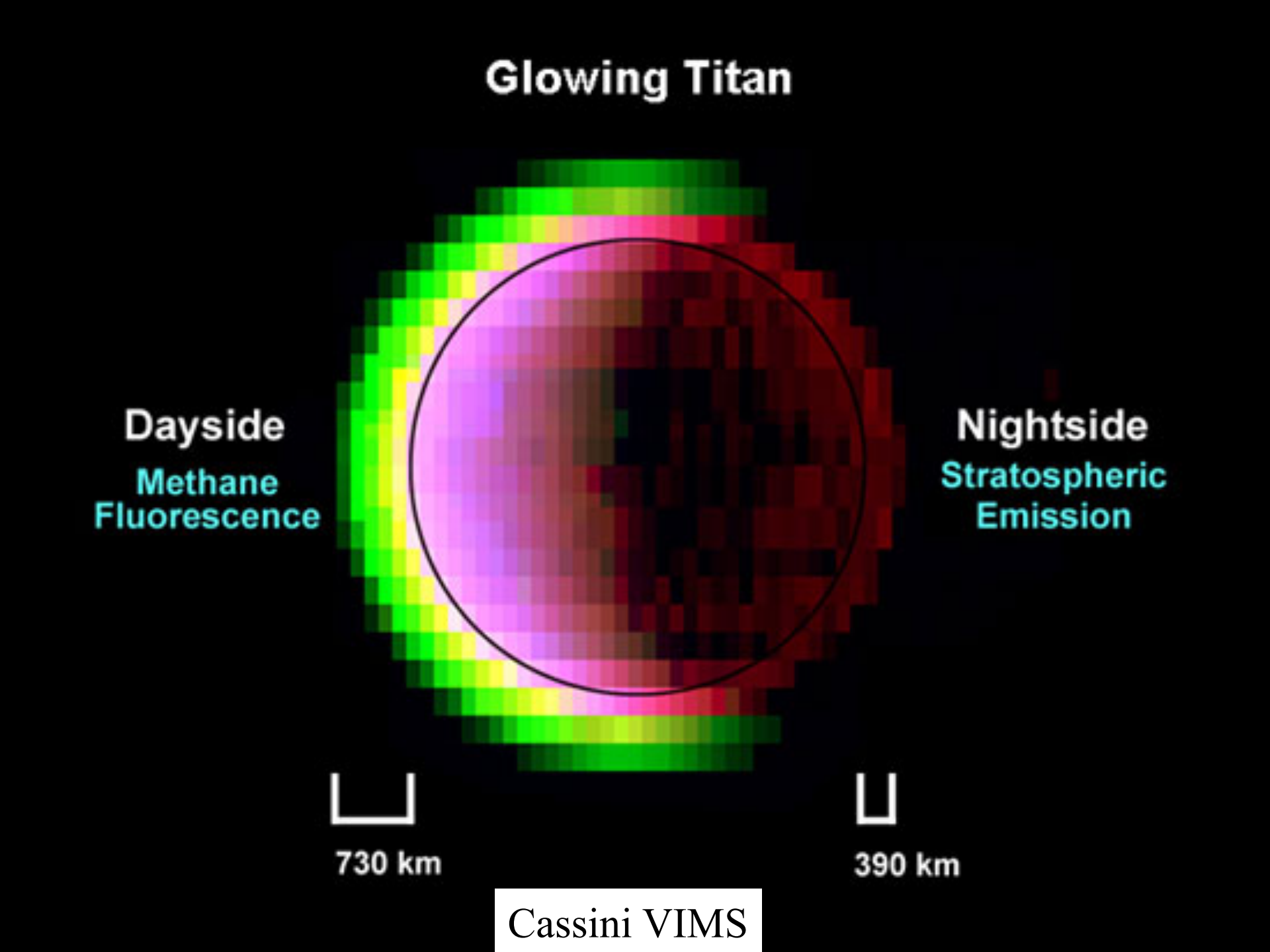




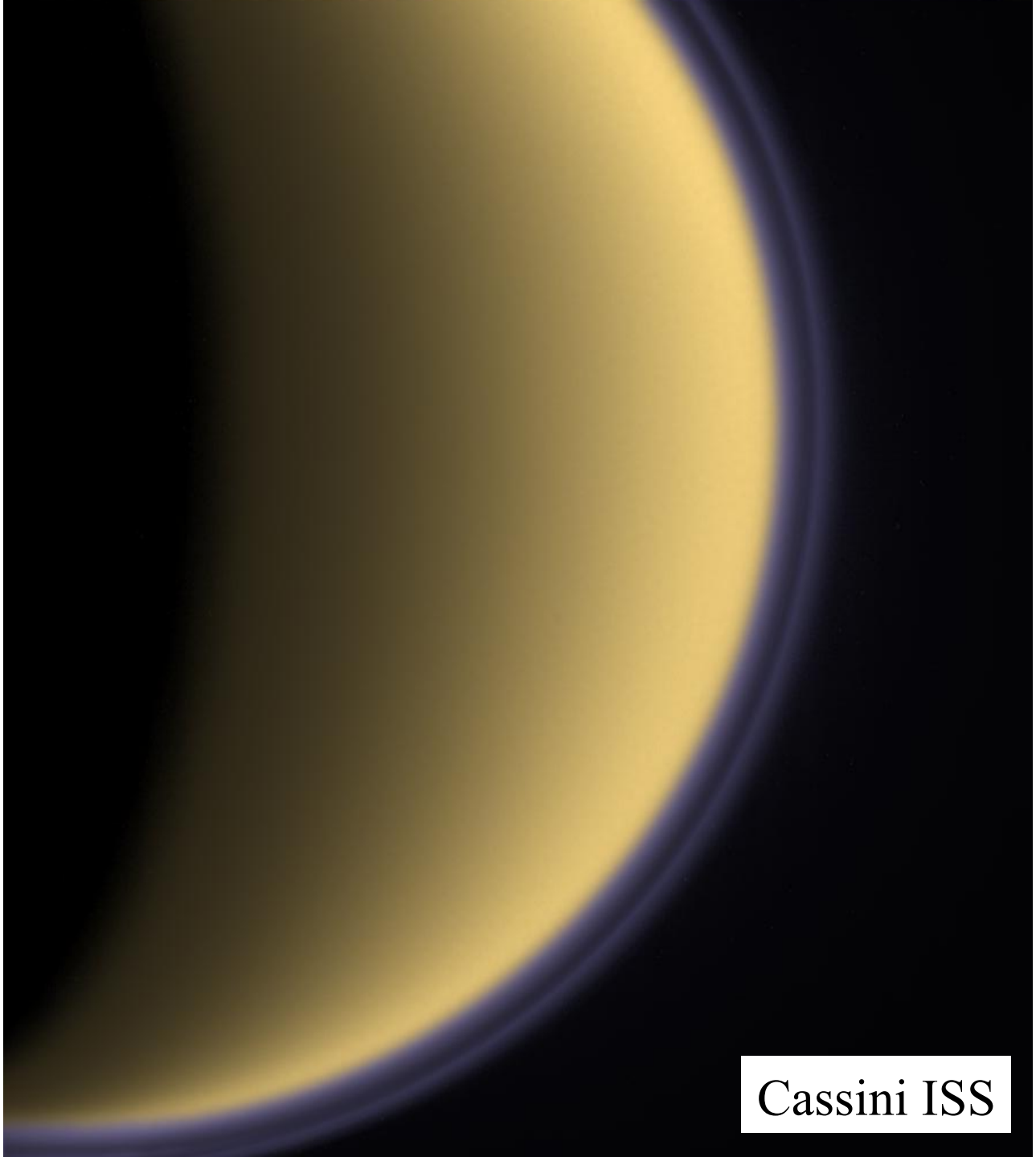
Cassini VIMS

Cassini VIMS

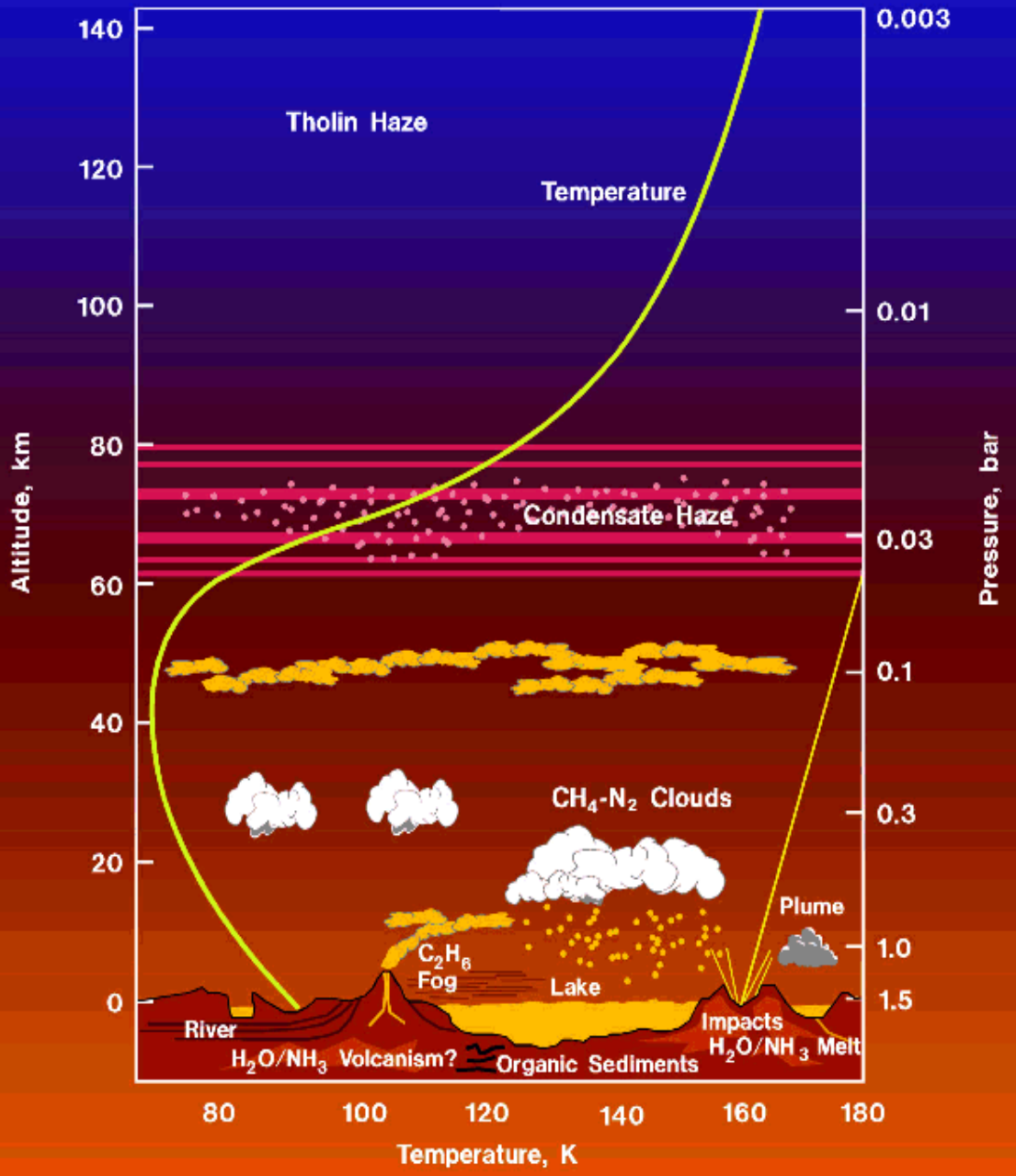


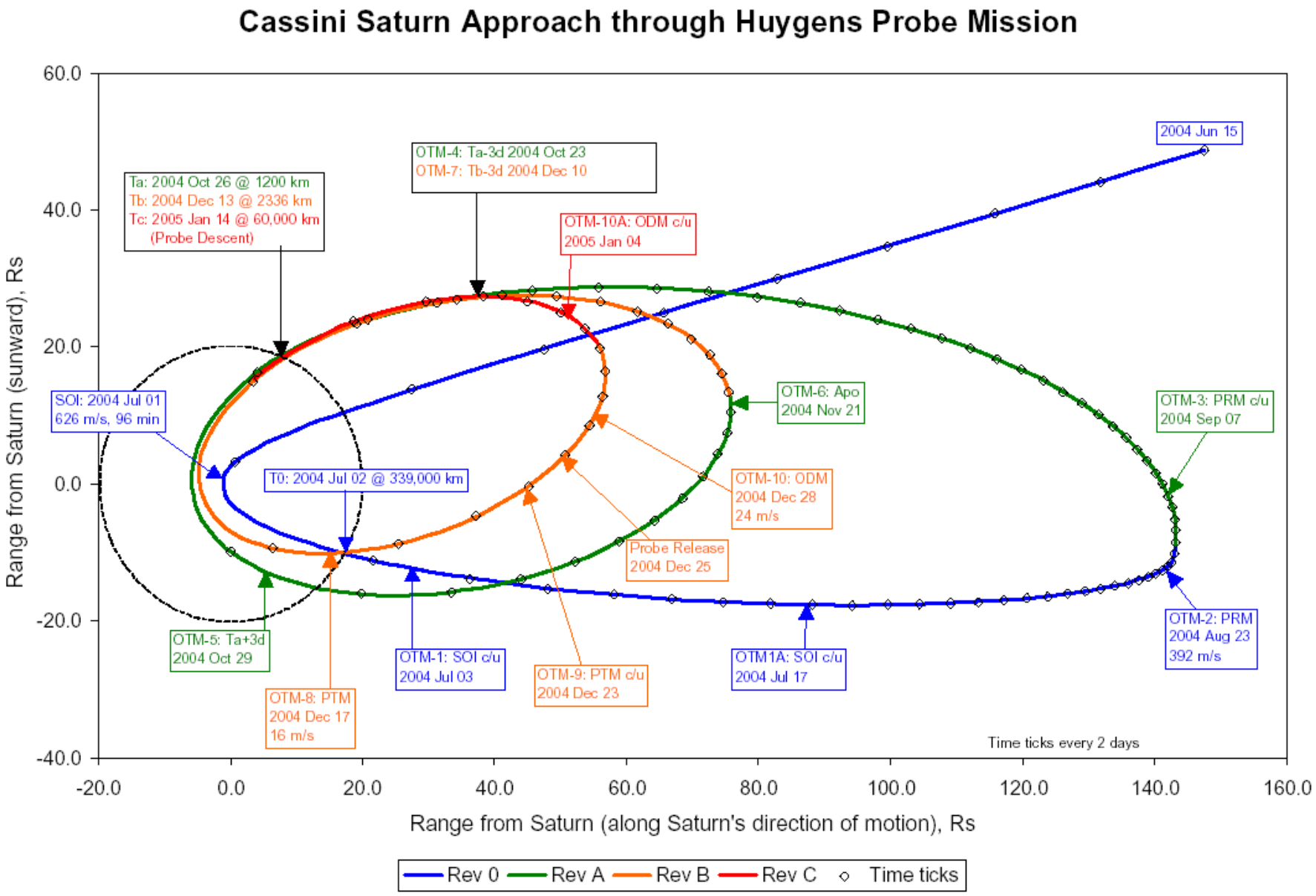


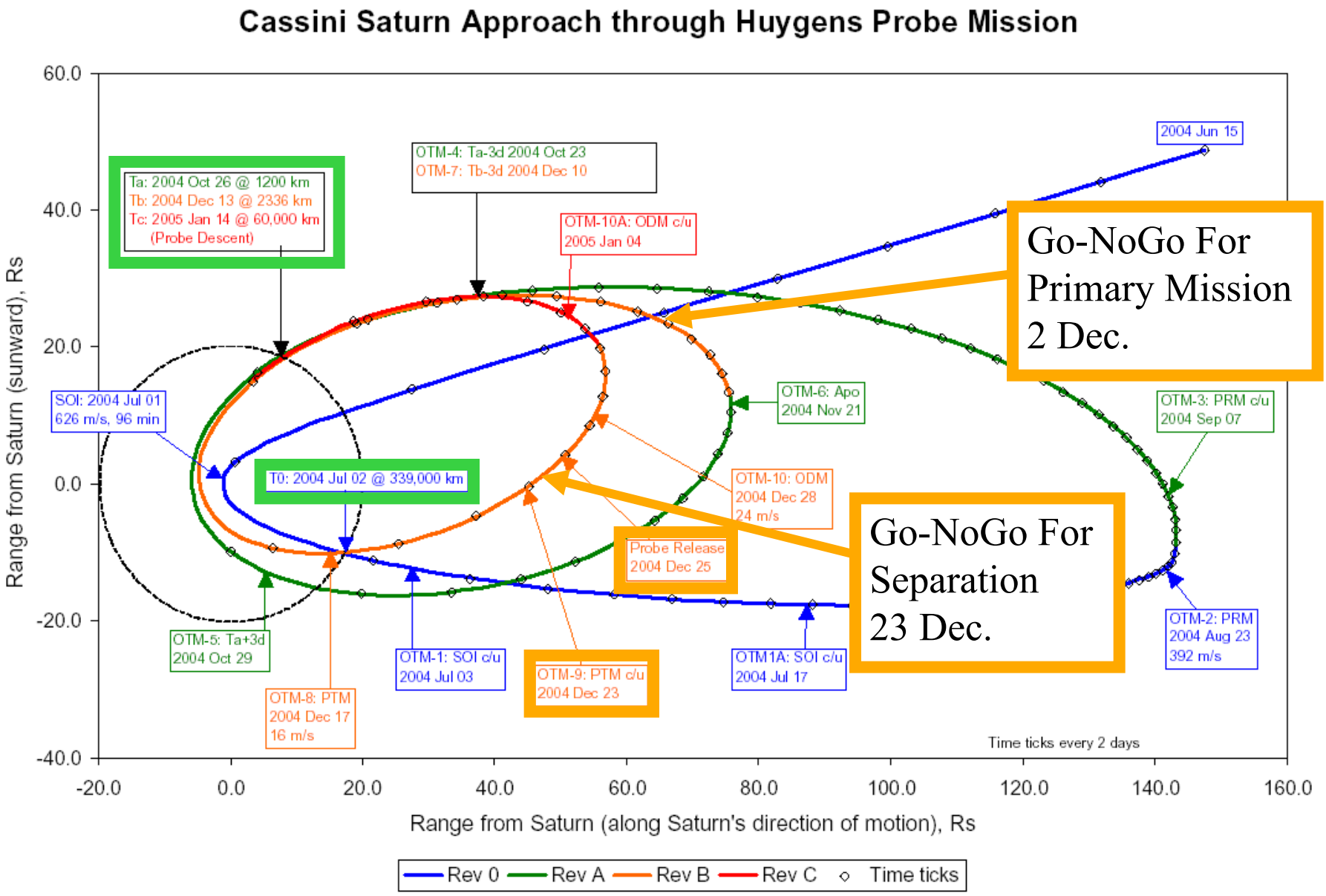
Cassini VIMS



Cassini ISS


Tholin Haze
Temperature
Condensate Haze
CH_4-N_2 Clouds
Plume
C_2H_6
Fog
Lake
River
H_2O/NH_3 Volcanism?
Organic Sediments
Impacts
H_2O/NH_3 Melt
Altitude, km
Pressure, bar
Temperature, K
140
120
100
80
60
40
20
0
0.003
0.01
0.03
0.1
0.3
1.0
1.5
80
100
120
140
160
180


Cassini Saturn Approach through Huygens Probe Mission
Ta: 2004 Oct 26 @ 1200 km
Tb: 2004 Dec 13 @ 2336 km
Tc: 2005 Jan 14 @ 60,000 km
(Probe Descent)
OTM-4: Ta-3d 2004 Oct 23
OTM-7: Tb-3d 2004 Dec 10
OTM-10A: ODM c/u
2005 Jan 04
2004 Jun 15
SOI: 2004 Jul 01
626 m/s, 96 min
T0: 2004 Jul 02 @ 339,000 km
OTM-6: Apo
2004 Nov 21
OTM-3: PRM c/u
2004 Sep 07
OTM-10: ODM
2004 Dec 28
24 m/s
Probe Release
2004 Dec 25
OTM-5: Ta+3d
2004 Oct 29
OTM-1: SOI c/u
2004 Jul 03
OTM-9: PTM c/u
2004 Dec 23
OTM1A: SOI c/u
2004 Jul 17
OTM-2: PRM
2004 Aug 23
392 m/s
OTM-8: PTM
2004 Dec 17
16 m/s
Time ticks every 2 days
Range from Saturn (sunward), Rs
Range from Saturn (along Saturn's direction of motion), Rs
60.0
40.0
20.0
0.0
-20.0
-40.0
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
Rev 0
Rev A
Rev B
Rev C
Time ticks


Cassini Saturn Approach through Huygens Probe Mission
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OTM-4: Ta-3d 2004 Oct 23
OTM-7: Tb-3d 2004 Dec 10
OTM-10A: ODM c/u
2005 Jan 04
2004 Jun 15
Go-NoGo For
Primary Mission
2 Dec.
SOI: 2004 Jul 01
626 m/s, 96 min
OTM-6: Apo
2004 Nov 21
OTM-3: PRM c/u
2004 Sep 07
T0: 2004 Jul 02 @ 339,000 km
OTM-10: ODM
2004 Dec 28
24 m/s
Probe Release
2004 Dec 25
Go-NoGo For
Separation
23 Dec.
OTM-5: Ta+3d
2004 Oct 29
OTM-1: SOI c/u
2004 Jul 03
OTM-9: PTM c/u
2004 Dec 23
OTM1A: SOI c/u
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392 m/s
OTM-8: PTM
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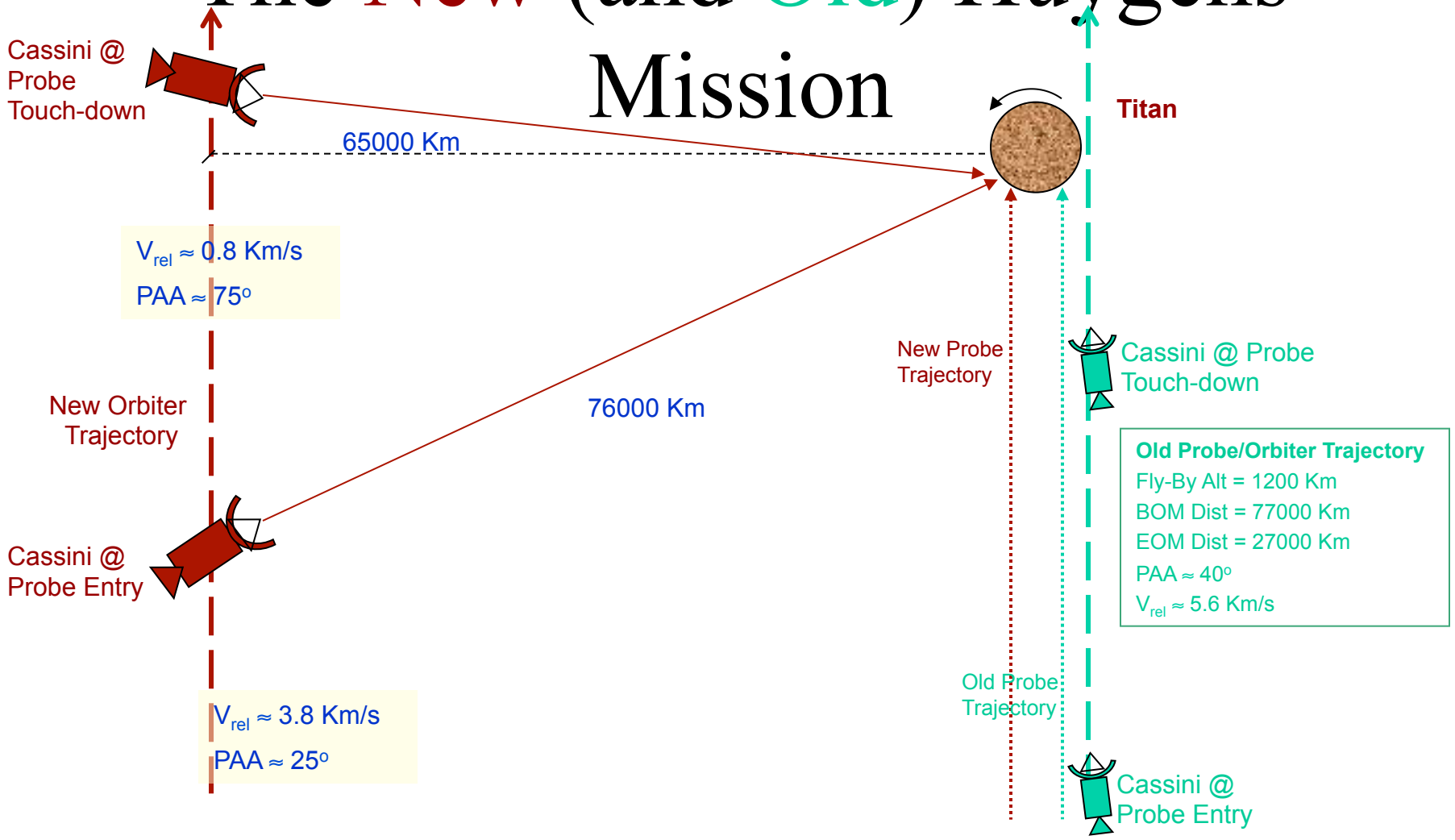
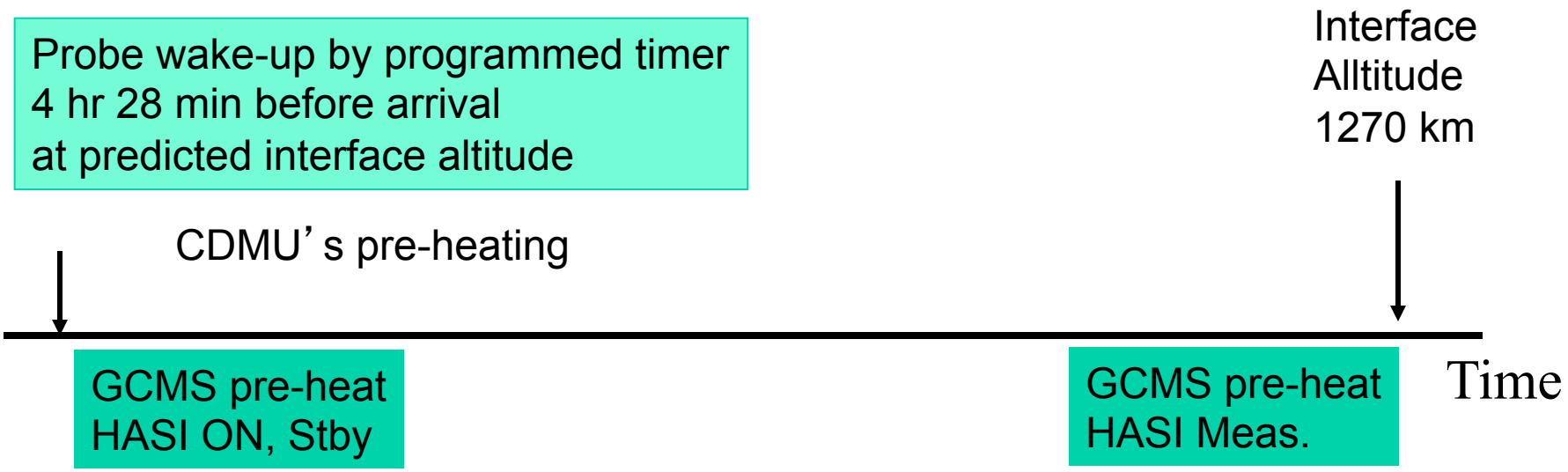
Time ticks every 2 days
Range from Saturn (sunward), Rs
60.0
40.0
20.0
0.0
-20.0
-40.0
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
Range from Saturn (along Saturn's direction of motion), Rs
Rev 0
Rev A
Rev B
Rev C
Time ticks

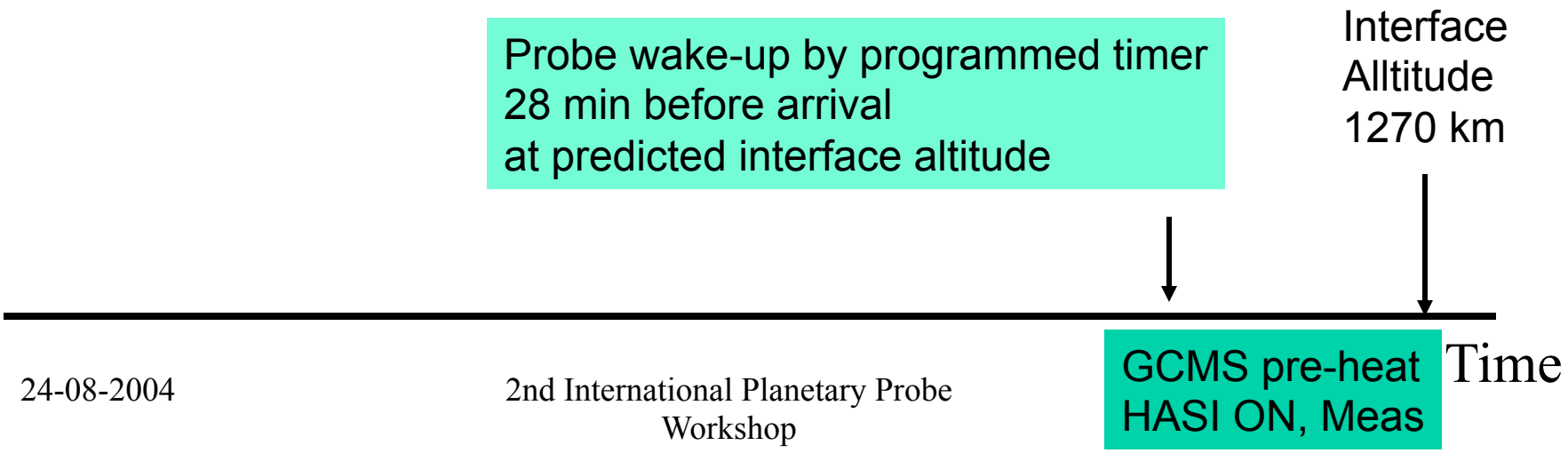
The New (and Old) Huygens Mission

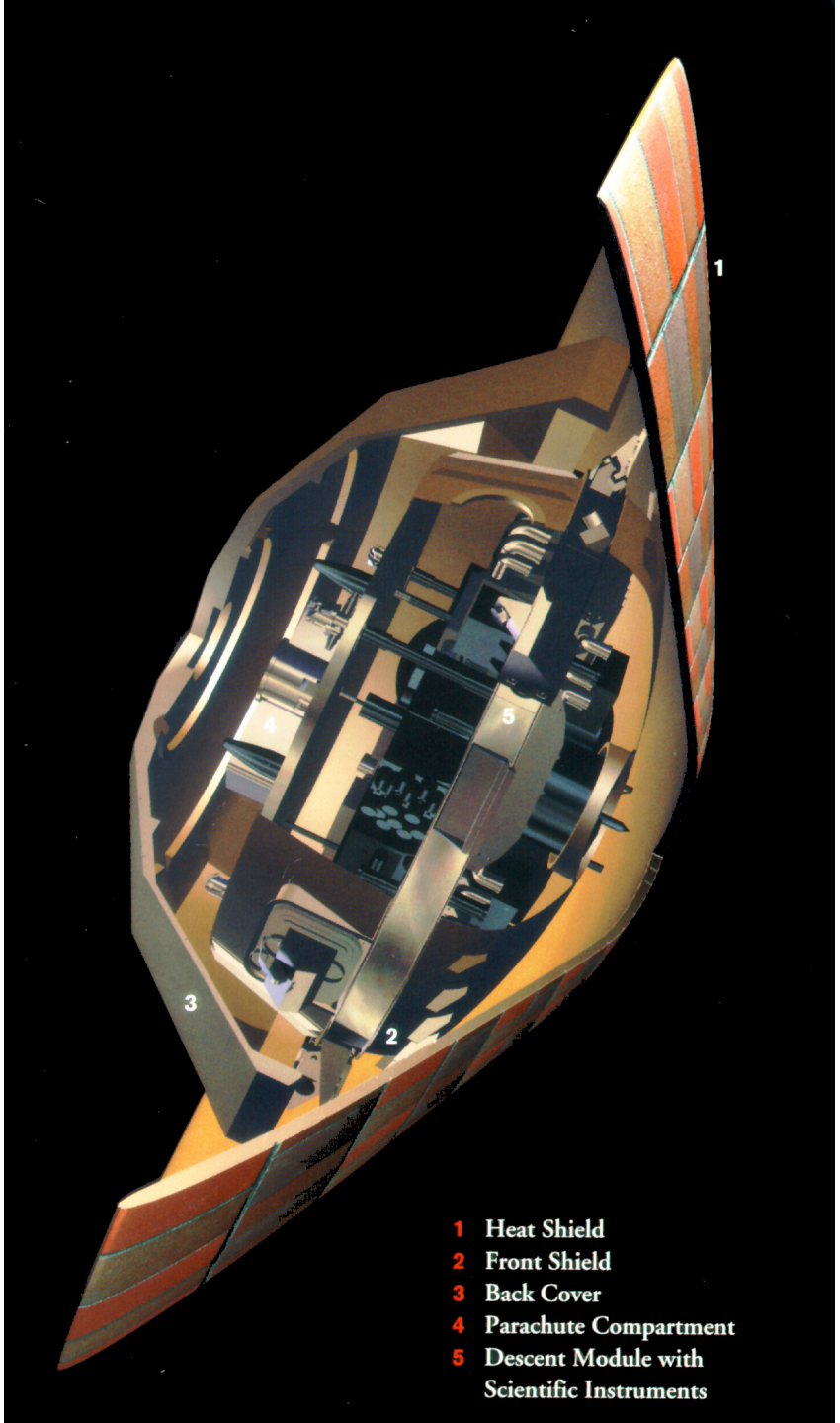


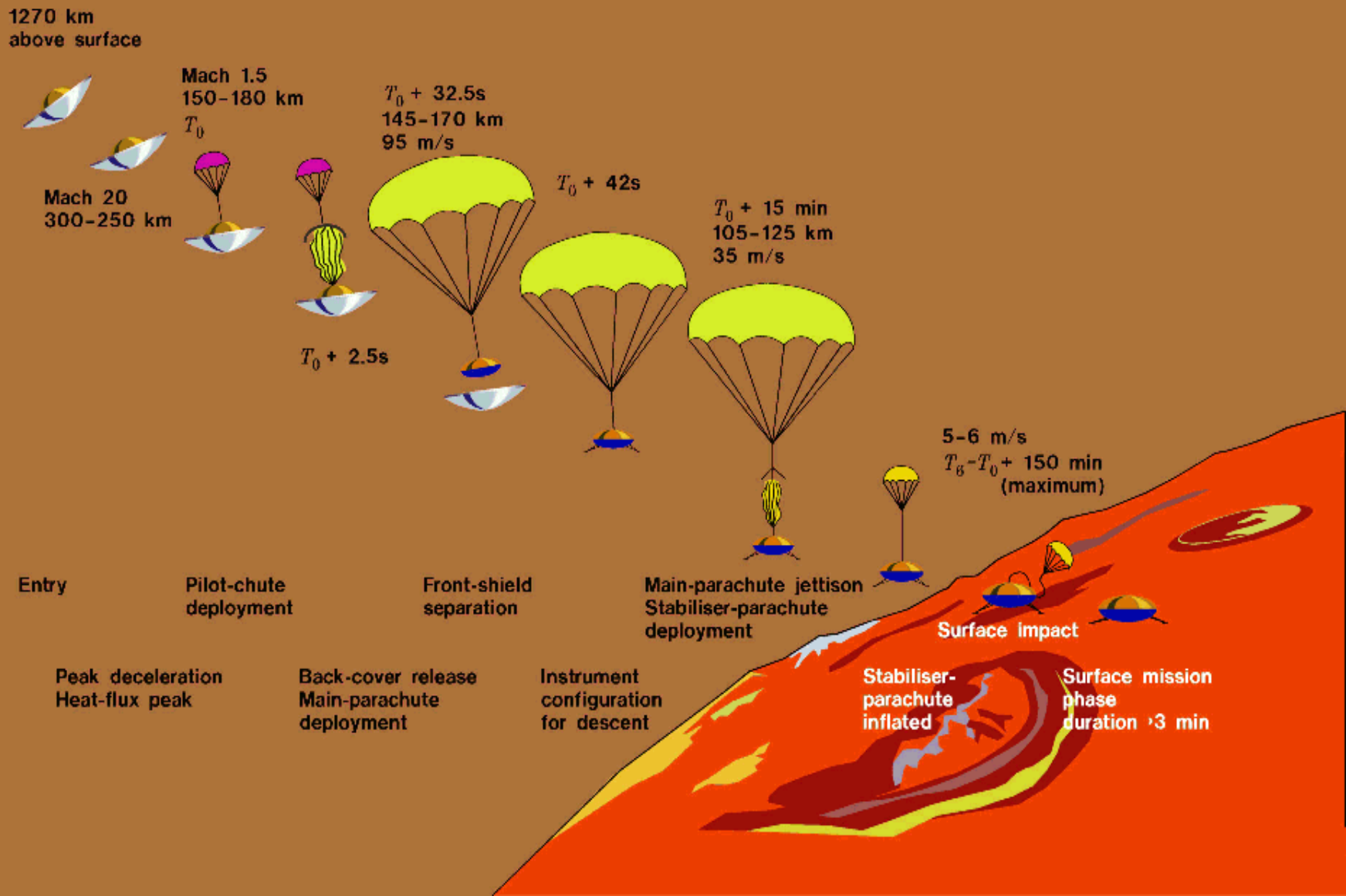
Baseline scenario: Pre-heating



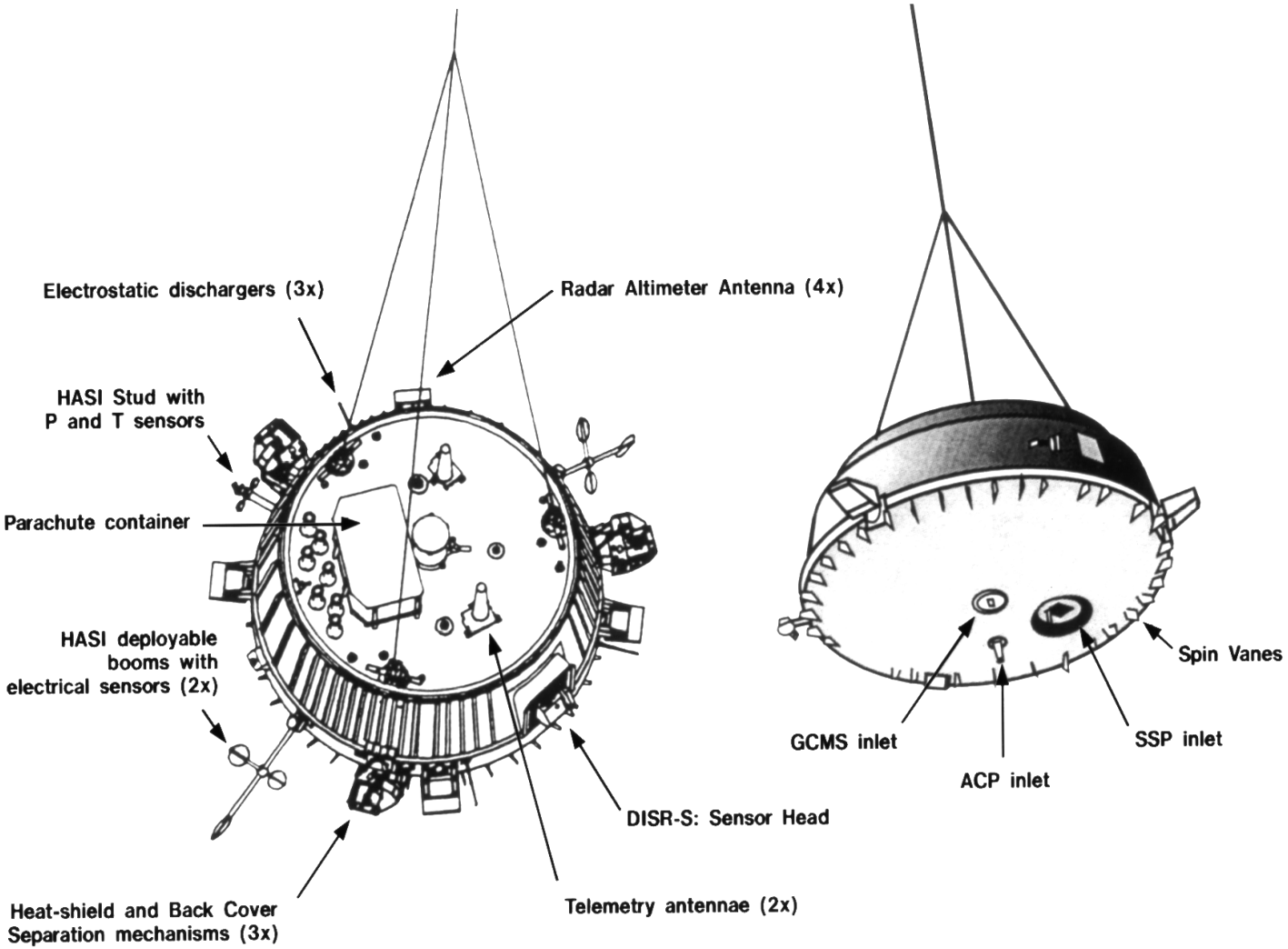
Back-up scenario: No pre-heating




1
2
3
4
5
1 Heat Shield
2 Front Shield
3 Back Cover
4 Parachute Compartment
5 Descent Module with Scientific Instruments


1270 km
above surface
Mach 1.5
150–180 km
T_0
Mach 20
300–250 km
T_0 + 32.5s
145–170 km
95 m/s
T_0 + 42s
T_0 + 15 min
105–125 km
35 m/s
T_0 + 2.5s
5–6 m/s
T_E–T_0 + 150 min
(maximum)
Entry
Pilot-chute deployment
Front-shield separation
Main-parachute jettison
Stabiliser-parachute deployment
Surface impact
Peak deceleration
Heat-flux peak
Back-cover release
Main-parachute deployment
Instrument configuration for descent
Stabiliser-parachute inflated
Surface mission phase duration ›3 min

The Huygens Science Payload



Huygens Payload

Huygens Atmospheric Structure Instrument (HASI). M. Fulchignoni (Paris 7/Obs Meudon)	T, P, γ, Winds, Turbulence, Conductivity; lightning; surface permittivity & radar reflectivity
Gas Chromatograph/Mass Spectrometer (GCMS), H. Niemann (NASA/GSFC)	Atmosphere composition; trace constituents; isotopic ratios; aerosol analysis
Aerosol Collector and Pyrolyzer (ACP) G. Israel (CNRS/SA Verrieres)	Aerosol sampling in two layers. Stepped pyrolysis (0 C, 200 C, 650 C); injection to GCMS
Descent Imager/Spectral Radiometer (DISR) M. Tomasko (U of Arizona)	Heat flux, energy budget, clouds, aerosols properties, surface imaging & composition
Doppler Wind Experiment (DWE) M. Bird (U of Bonn)	Zonal wind profile, turbulence
Surface Science package (SSP) J. Zarnecki (Open Univ.)	Surface state and composition at landing site. Atmospheric measurements

Huygens Payload & Ground-based Radio Signal Detection

Huygens Atmospheric Structure Instrument (HASI). M. Fulchignoni (Paris 7/Obs Meudon)	T, P, γ, Winds, Turbulence, Conductivity; lightning; surface permittivity & radar reflectivity
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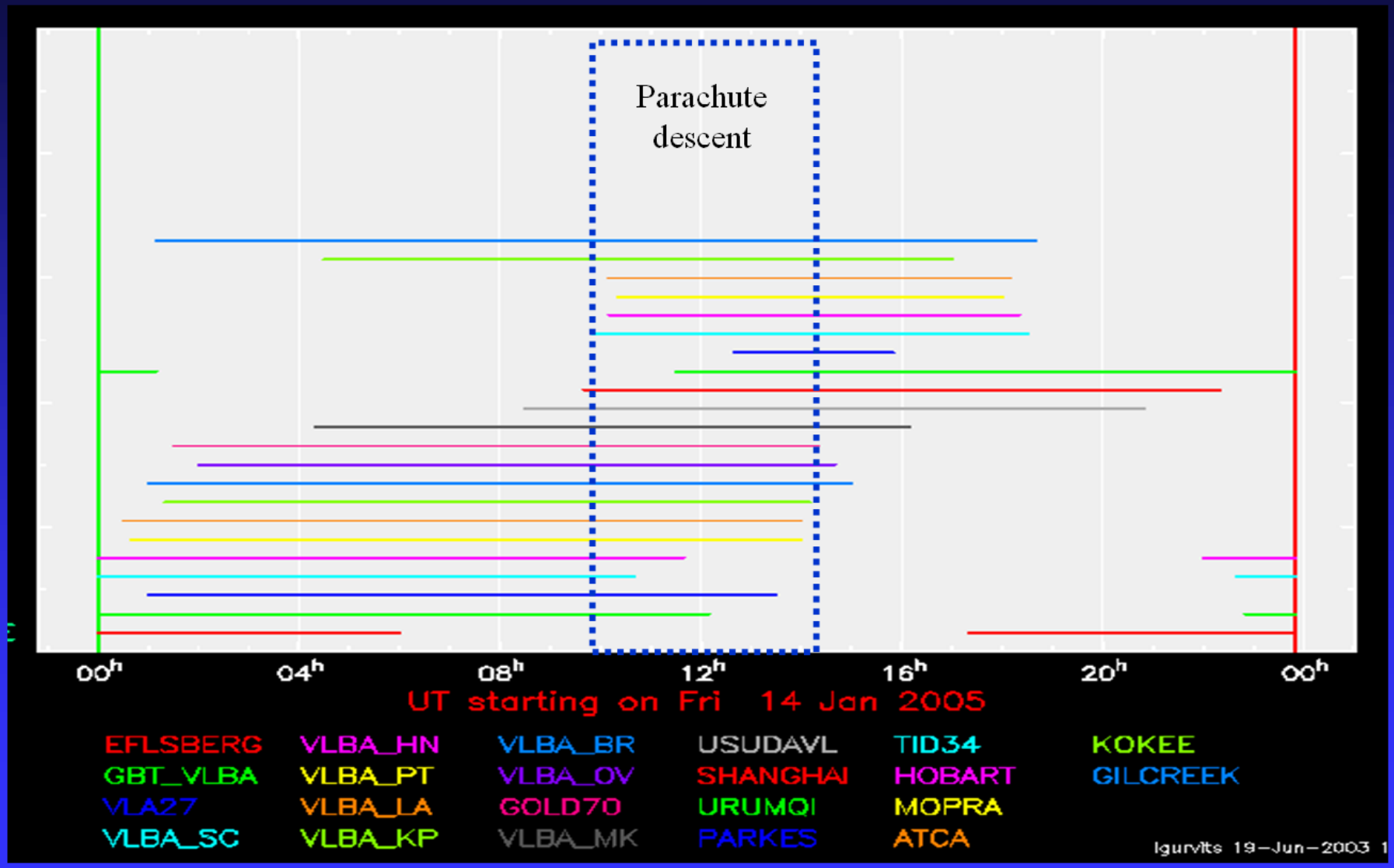
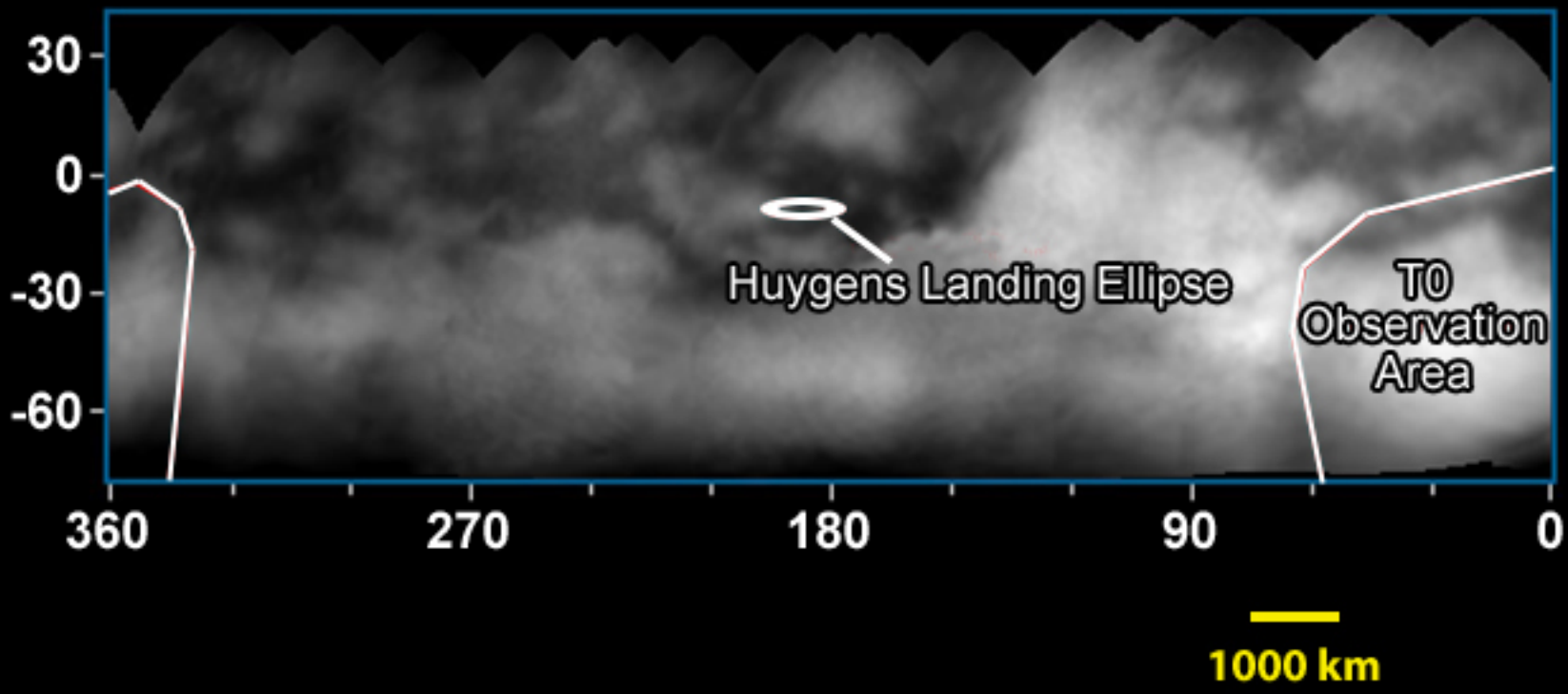
VLBI Probe signal carrier detection Ground-based DWE	Probe localisation to ~ km acc. in x-y plane; 2D wind measurements

Visibility of the H-Probe from radio telescopes



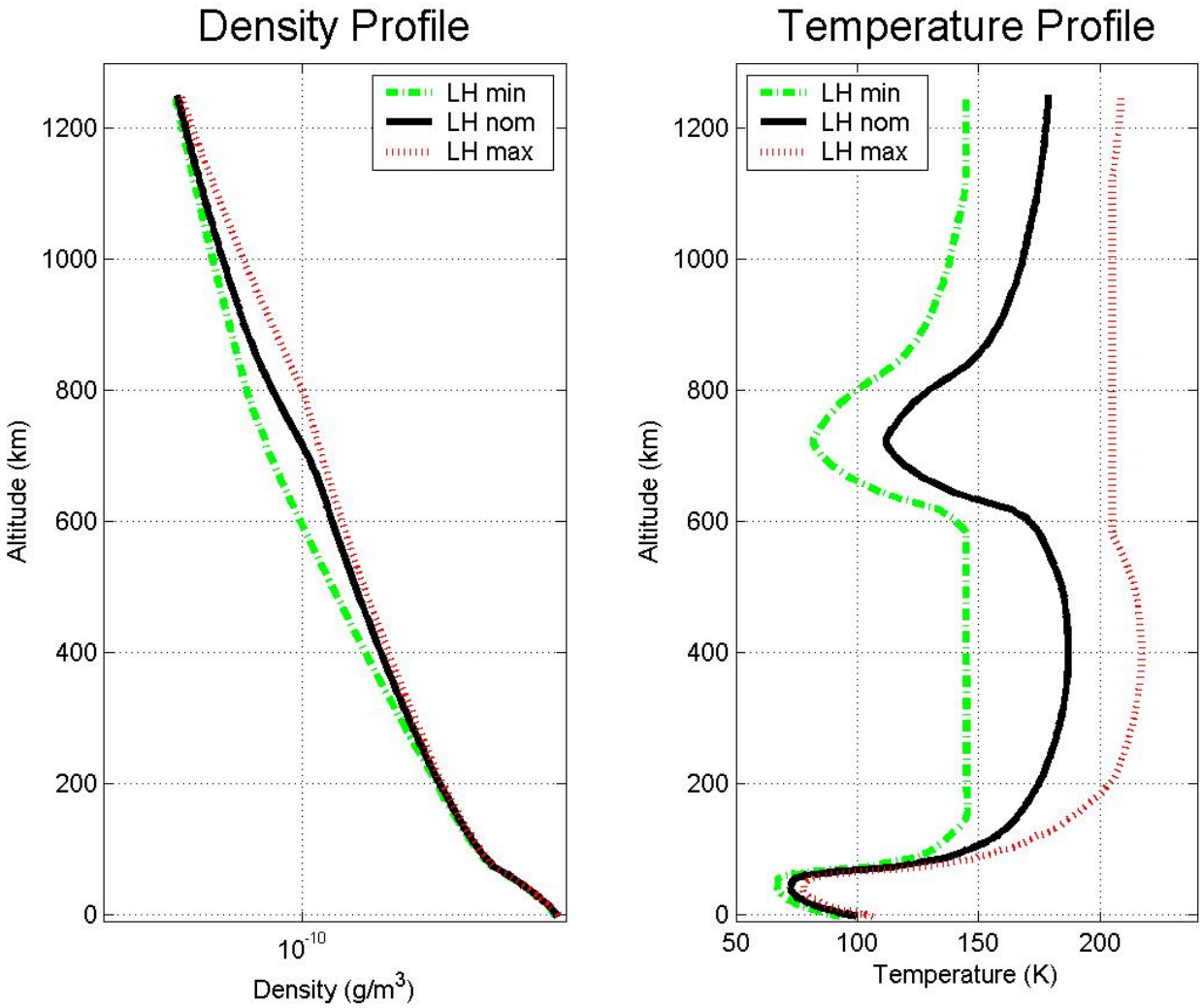

30
0
-30
-60
360
270
180
90
0
Huygens Landing Ellipse
T0
Observation
Area
1000 km

Engineering Status; On-going activities

TITAN Atmosphere environment

- Atmosphere Density, Pressure and Temperature models available:
  - Design model: Lellouch-Hunten (rec, min, max, 1986)
  - Updated model: Yelle (rec, min, max, 1994)
- Gravity Waves:
  - D. Strobel Model (single phase large amplitude profiles, 1994)
  - Analytical Model (J.P. Lebreton, 2004)
- Wind Model: so-called HRTF (Flasar model)
- Titan GRAM (disturbances on Yelle profiles - developed for aerocapture studies and used as is)

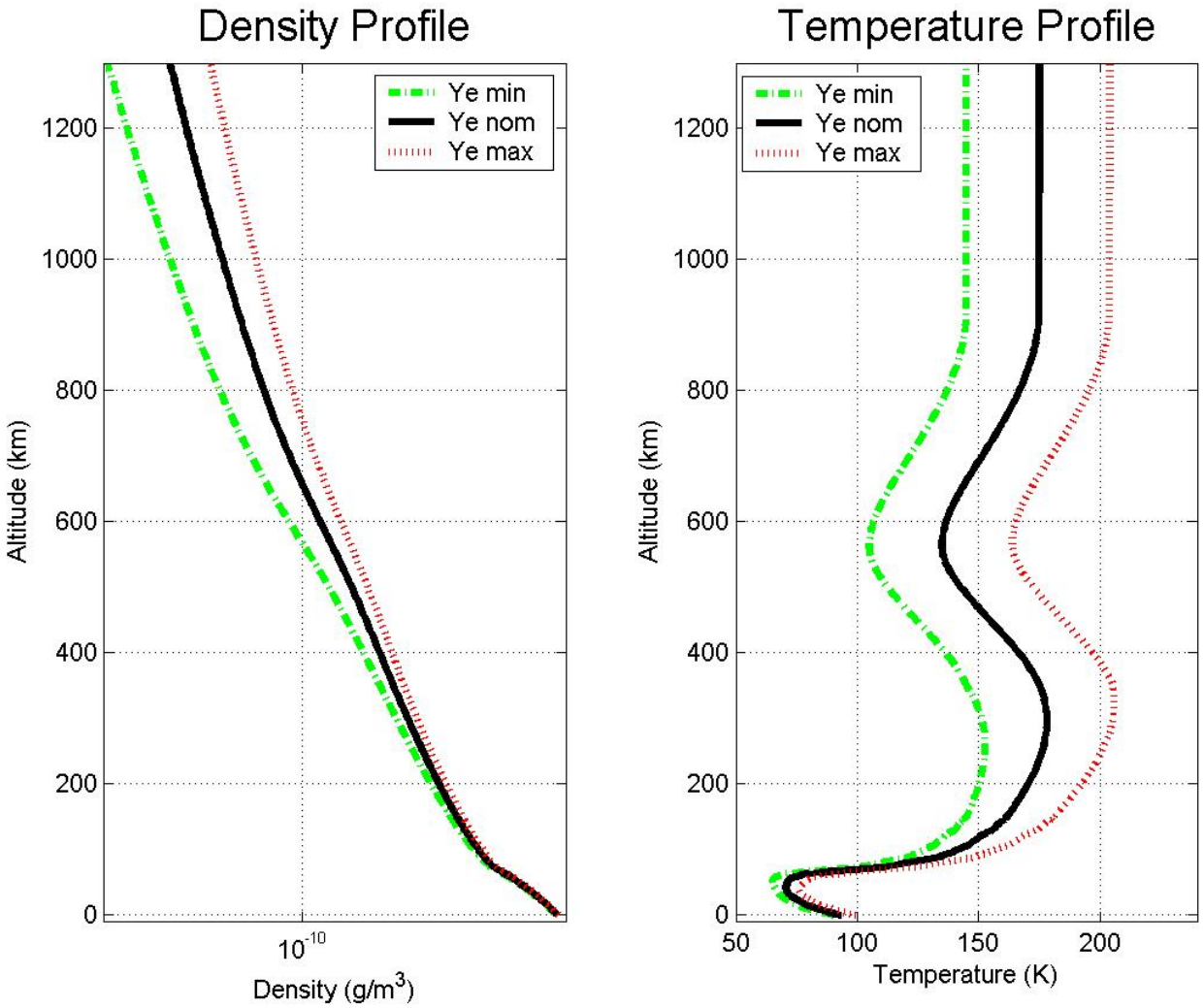
Lellouch-Hunten Model



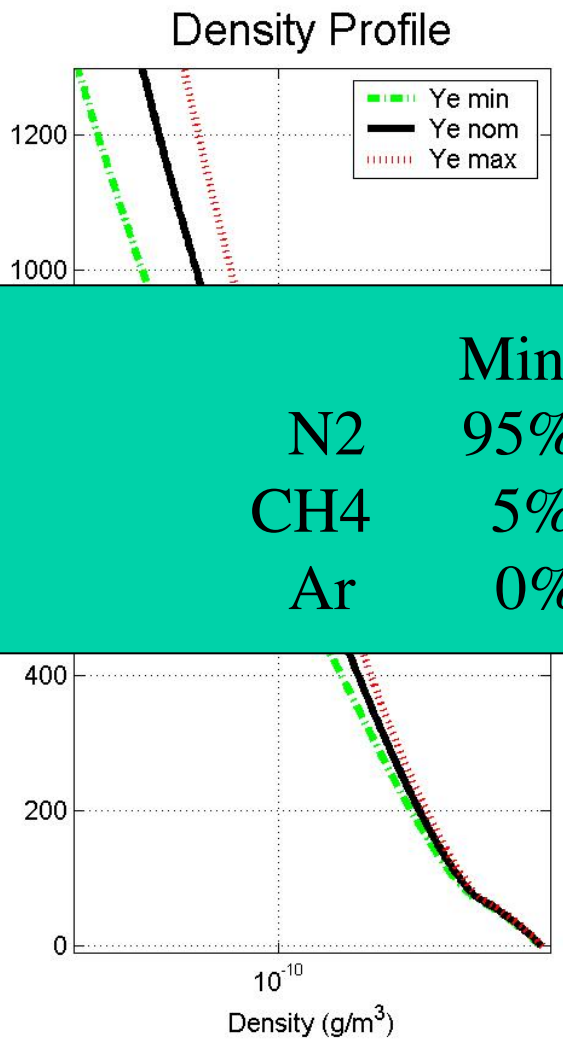
Three main components are Nitrogen (N2), Methane (CH4), and Argon (Ar).

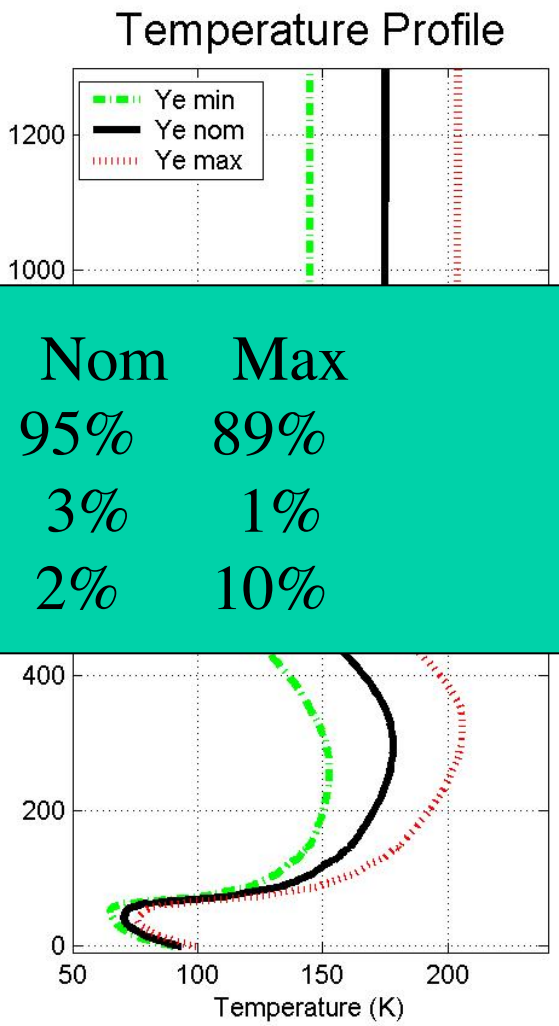
$0.5\% < X_{CH4}/X_{N2} < 3.5\%$; Relative molar abundance of Argon : $0 < X_{Ar}/X_{N2} < 27\%$.

Yelle Model


Density Profile
Ye min
Ye nom
Ye max
Altitude (km)
0
200
400
600
800
1000
1200
10^{-10}
Density (g/m^3)
Temperature Profile
Ye min
Ye nom
Ye max
Altitude (km)
0
200
400
600
800
1000
1200
50
100
150
200
Temperature (K)

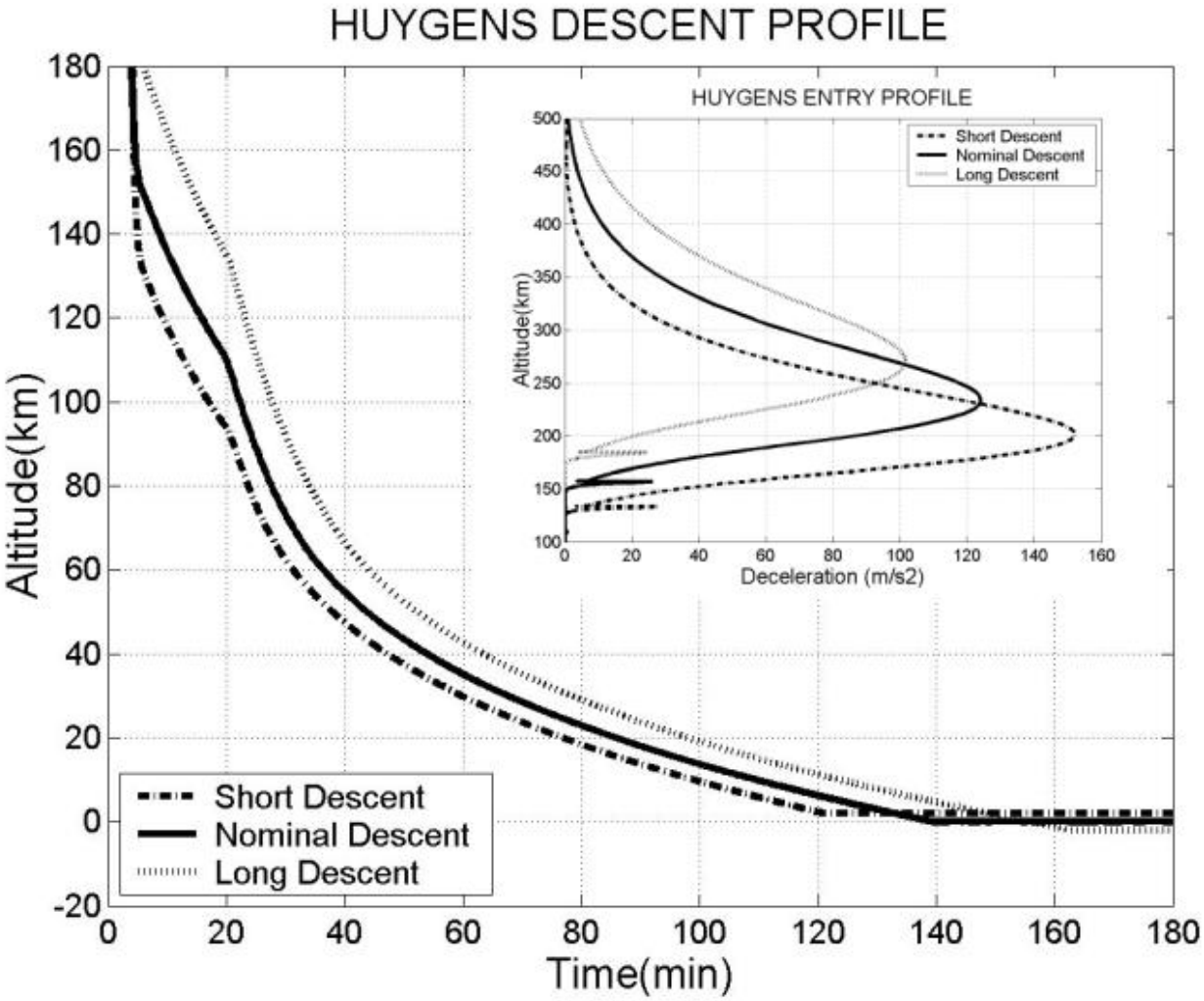
Yelle Model

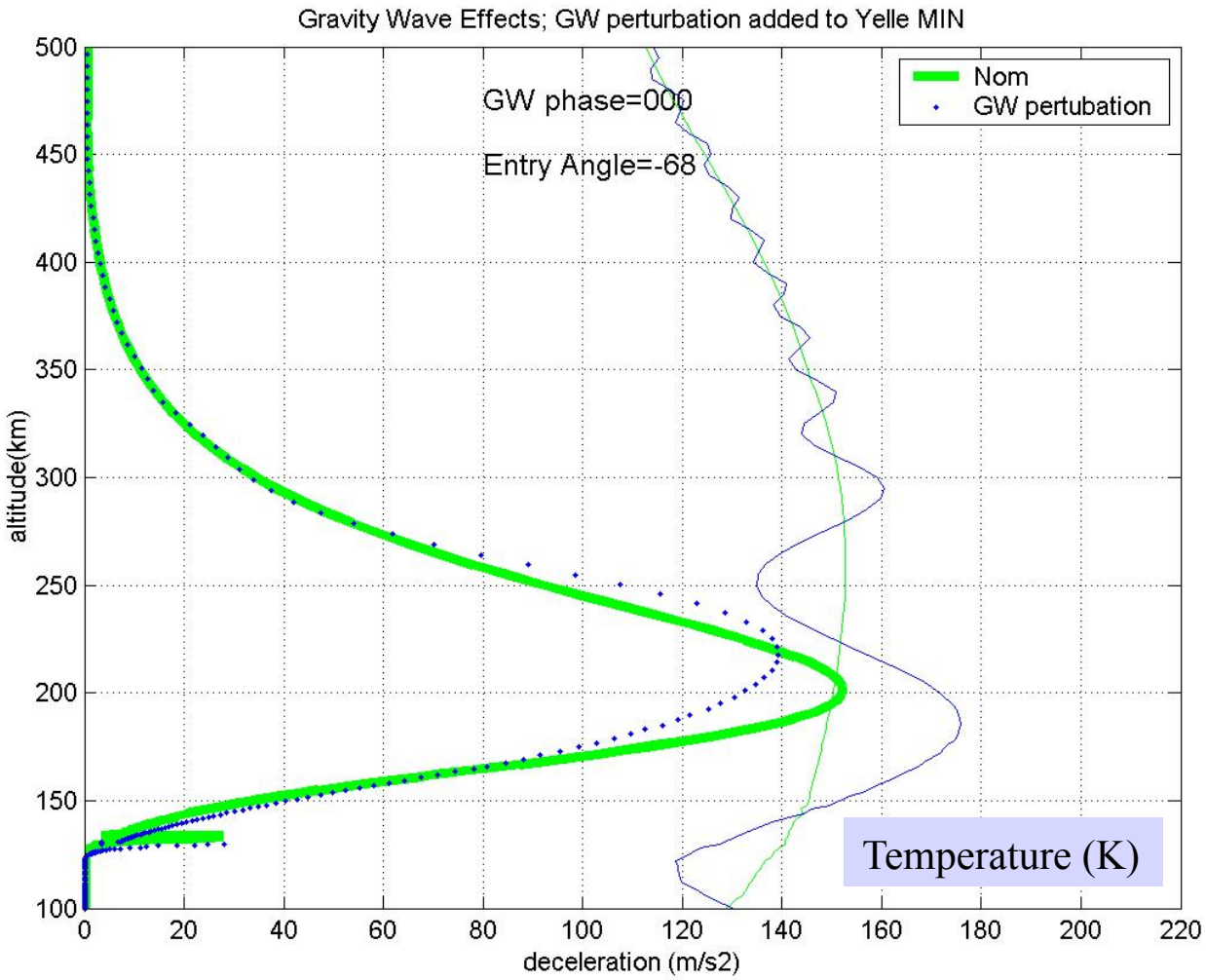


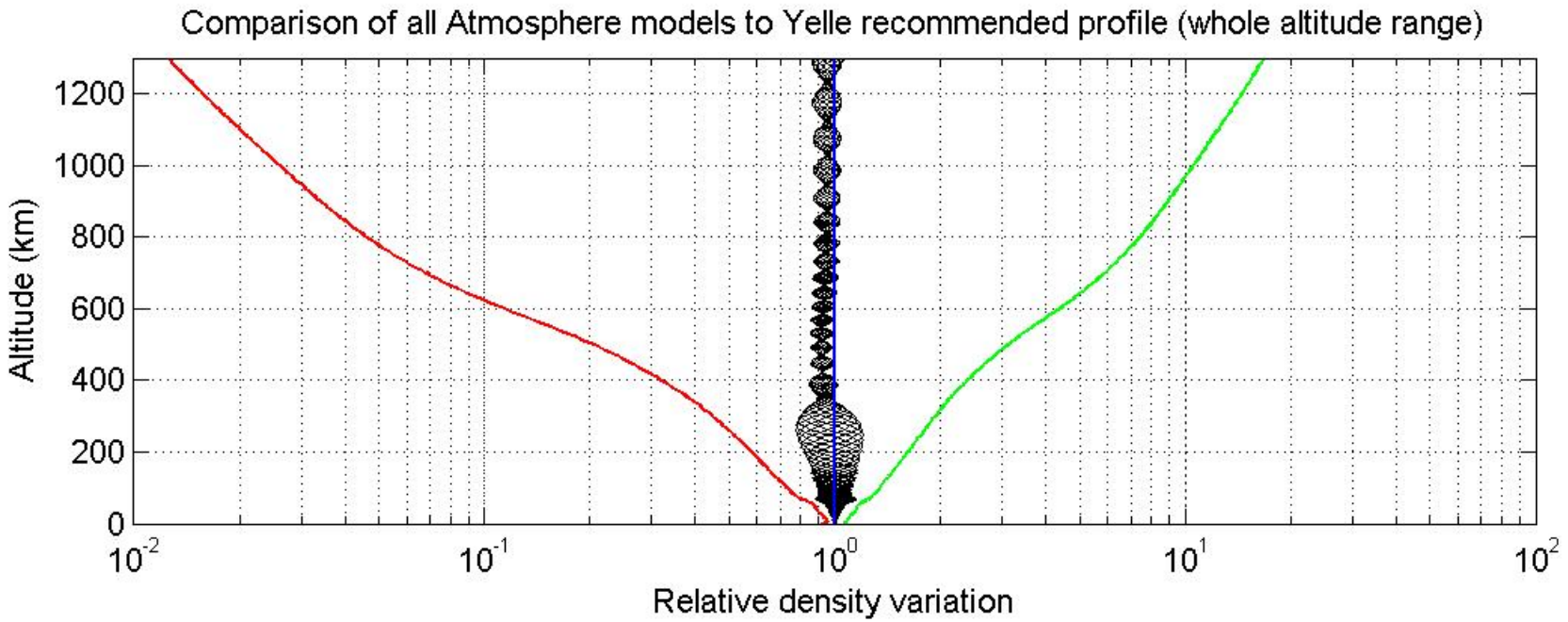


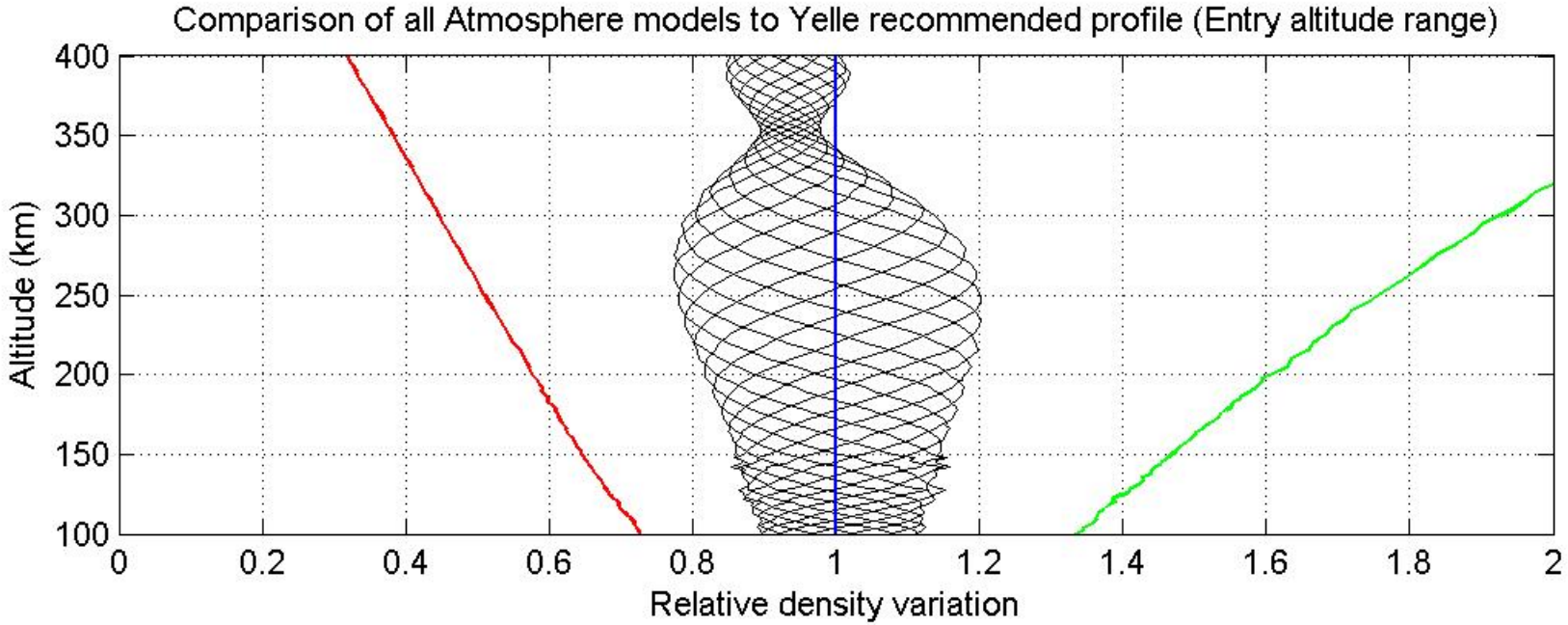
	Min	Nom	Max
N2	95%	95%	89%
CH4	5%	3%	1%
Ar	0%	2%	10%

Entry Altitude Range




Gravity Wave Effects; GW perturbation added to Yelle MIN
GW phase=000
Entry Angle=-68
Nom
GW pertubation
Temperature (K)
altitude(km)
deceleration (m/s2)
500
450
400
350
300
250
200
150
100
0
20
40
60
80
100
120
140
160
180
200
220


Comparison of all Atmosphere models to Yelle recommended profile (whole altitude range)
Altitude (km)
0
200
400
600
800
1000
1200
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Relative density variation


Comparison of all Atmosphere models to Yelle recommended profile (Entry altitude range)
Altitude (km)
100
150
200
250
300
350
400
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Relative density variation

ΔFAR Outcome (Overall)

The Board concluded that the objectives of the review have been met. No show-stopper has been identified. The implementation of the mission should proceed as planned.

However, it is urgently needed to set-up a special activity to finalise the re-validation of the entry corridor and to assess whether the residual risks are equally balanced as the nominal value was shifted from the FAR baseline of –64 (±4) ° to –65(±3) °.

The following major short-term actions have been agreed:

- Re-assess worst case atmosphere engineering models: by end of March
- Independent assessment of the EADS and NASA/Ames heat flux calculations: by end of March
- Perform heat-shield material (AQ60) UV transparency tests (at ESTEC and at NASA/Ames): by end of April
- Perform parachute model validation with MER data (pending MER data availability from NASA/JPL to ESA): Mid-April

On-going activities

- Re-validation of entry and descent performance
  - Heat flux recently re-assessed: 1400 ➔ 2000 kW/m2
  - TPS and overall System performance under ~ 2000 kW/m2
  - Heat-flux re-evaluation (ESTEC, EM2C, NASA/AMES, EADS, Alcatel)
  - Heat shield tile transparency tests to CN violet radiation
  - Parachute deployment loads
  - Entry angle confirmation (baseline -65 º ± 3°)
- Validation of atmosphere model
  - T0 (3rd July) Cassini orbiter observation
  - Relevant ground based observations (e. g. occultation of Nov. 2003)
  - Planned Ta Cassini Orbiter observations (26 October 2004)
  - Planned Tb Cassini Orbiter observation (13 Dec. 2004)

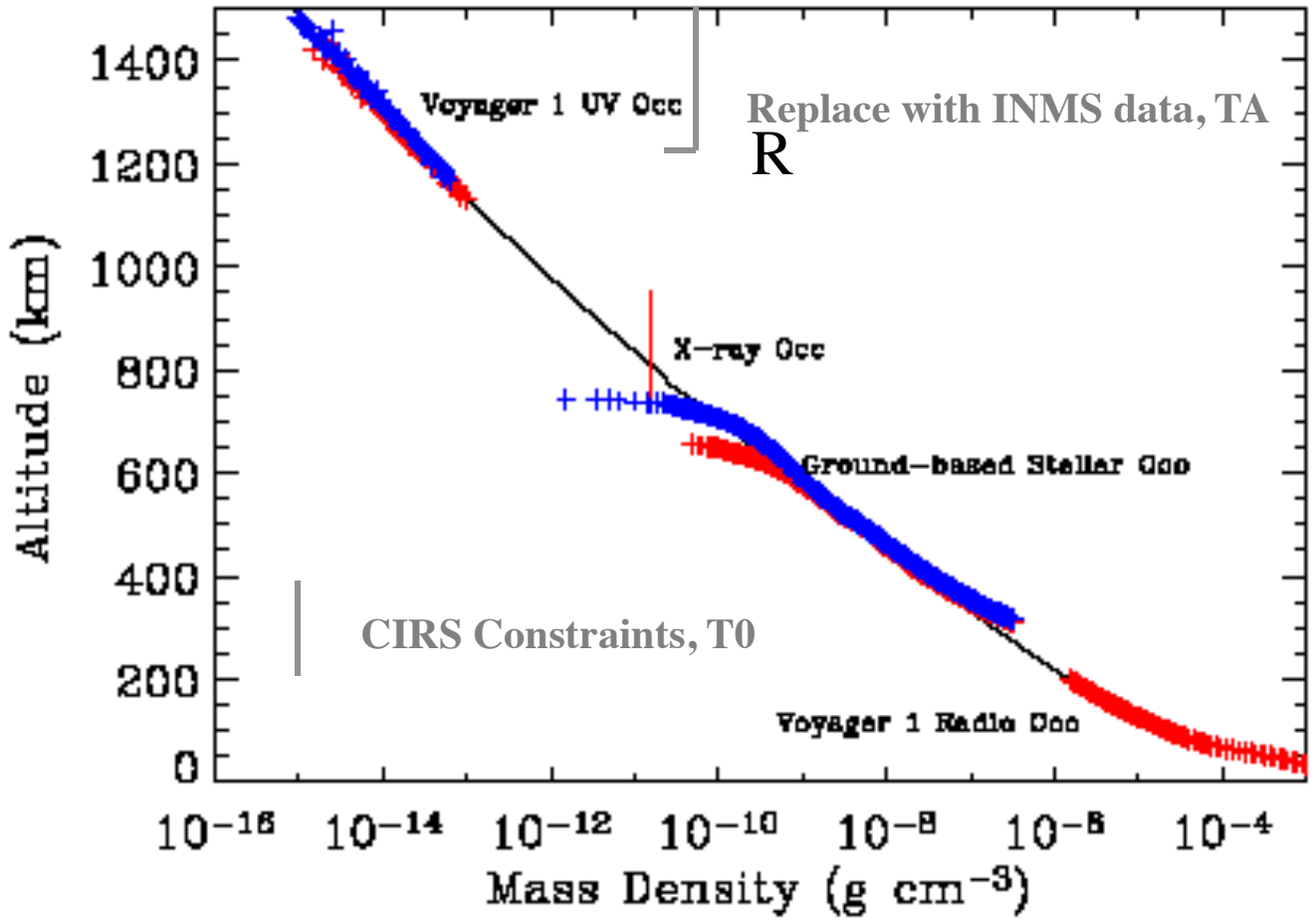
On-going activities (2)

- Huygens designed for (cumulated) worst case conditions
  - Atmosphere Model Composition
  - Gravity waves
  - Failure cases
- Monte-Carlo study based on TitanGRAM
- Mission baseline re-validation and margins to be clarified by early October
- NASA/ESA Review in planning (Sept/Oct ?-Nov)

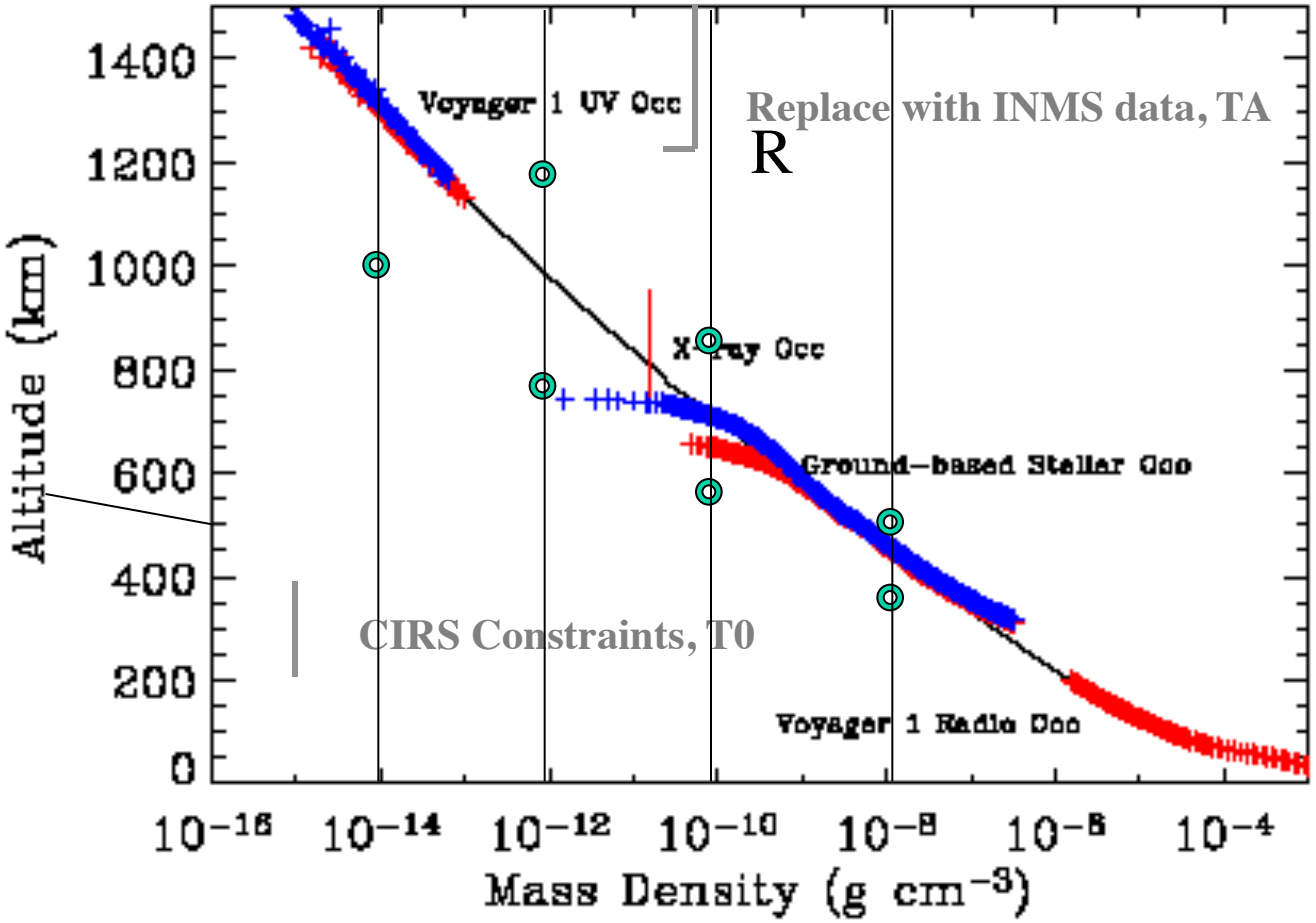
Huygens key operational milestones

- T0: 3 July; T0 workshop: 8/9 Sept. at NASA/GSFC
- Titan atmosphere models validation/update#1: 30 Sept.
- PCO#15: 14th September; battery depassivation#1
- Ta: 26 October; Ta Workshop: 15 Nov at JPL
- Titan atmosphere models validation/update#2: 25 Nov.
- PCO#16: 23 November; battery depassivation#2
- GO/NOGO for primary mission: 2 Dec.
- Tb: 13 Dec; Titan atmosphere report: 15 Dec.
- PTM: Approval: 15 Dec; Execution 17 Dec.
- Probe pre-separation configuration: 21 Dec
- GO/NOGO for Probe separation: 23 Dec.
- Probe Release: 25 Dec.
- Probe Entry: 14 January 09:07 UTC

What Happens Next re. atmosphere validation ?



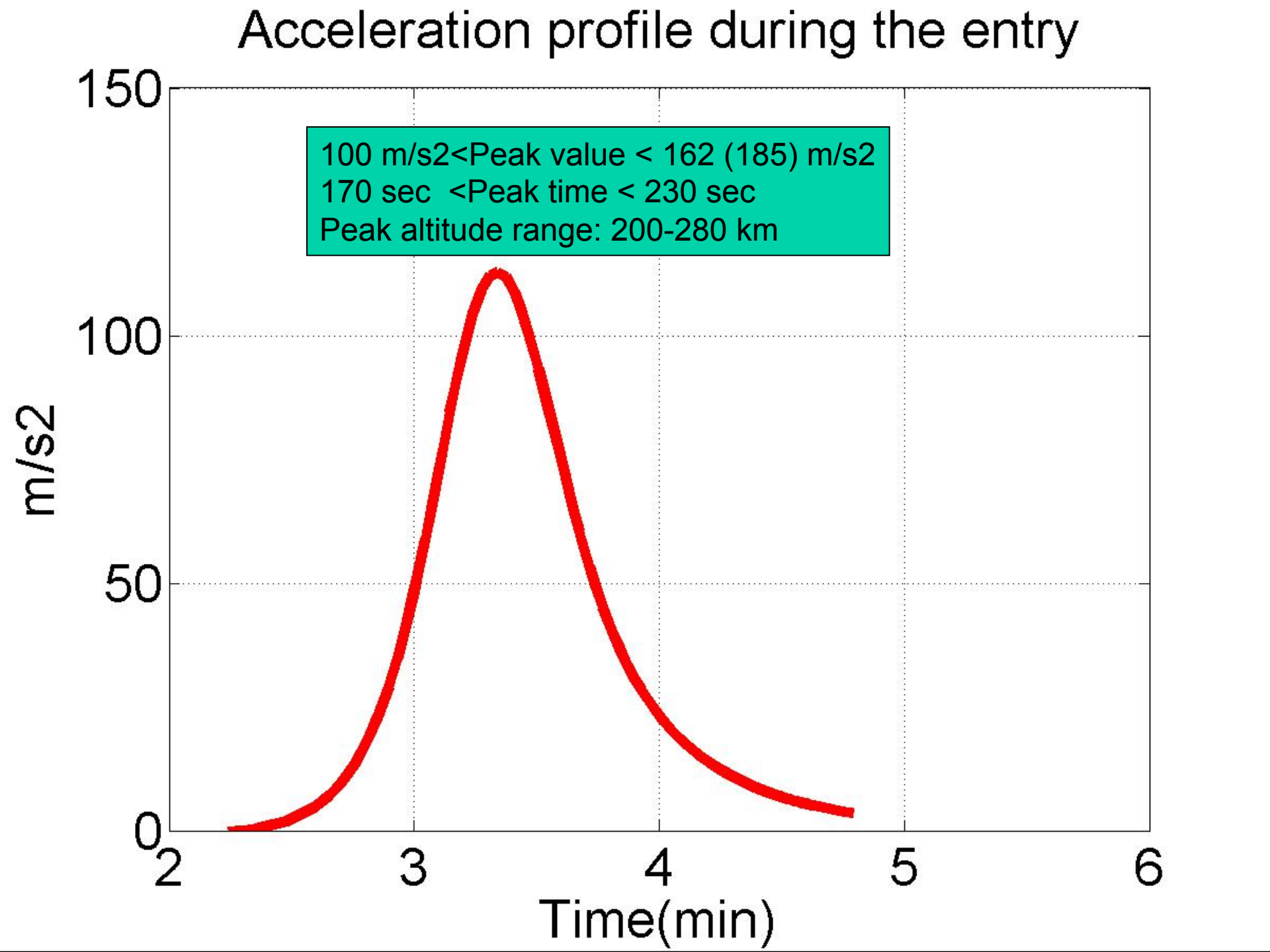
What Happens Next
re. atmosphere validation ?

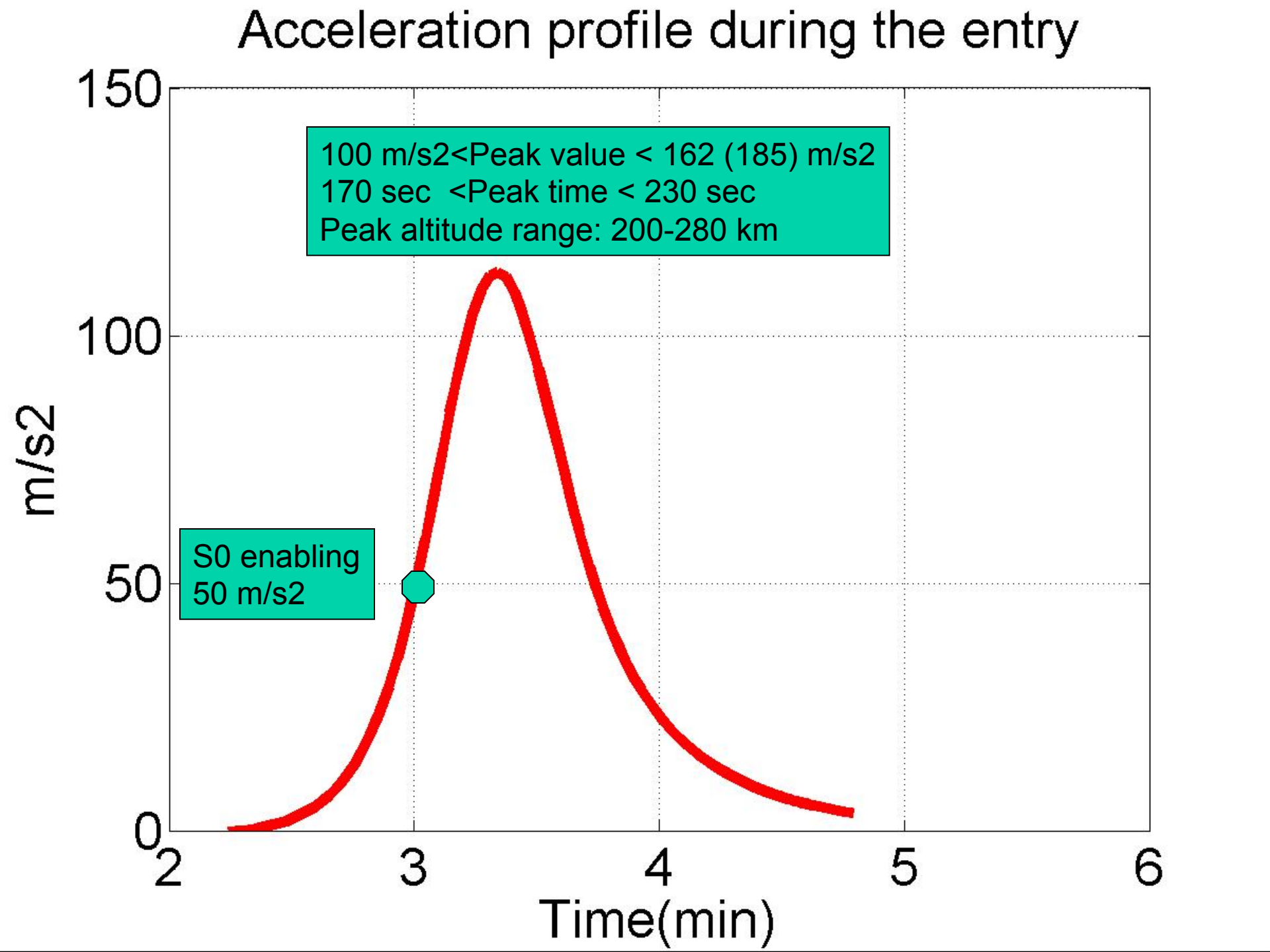


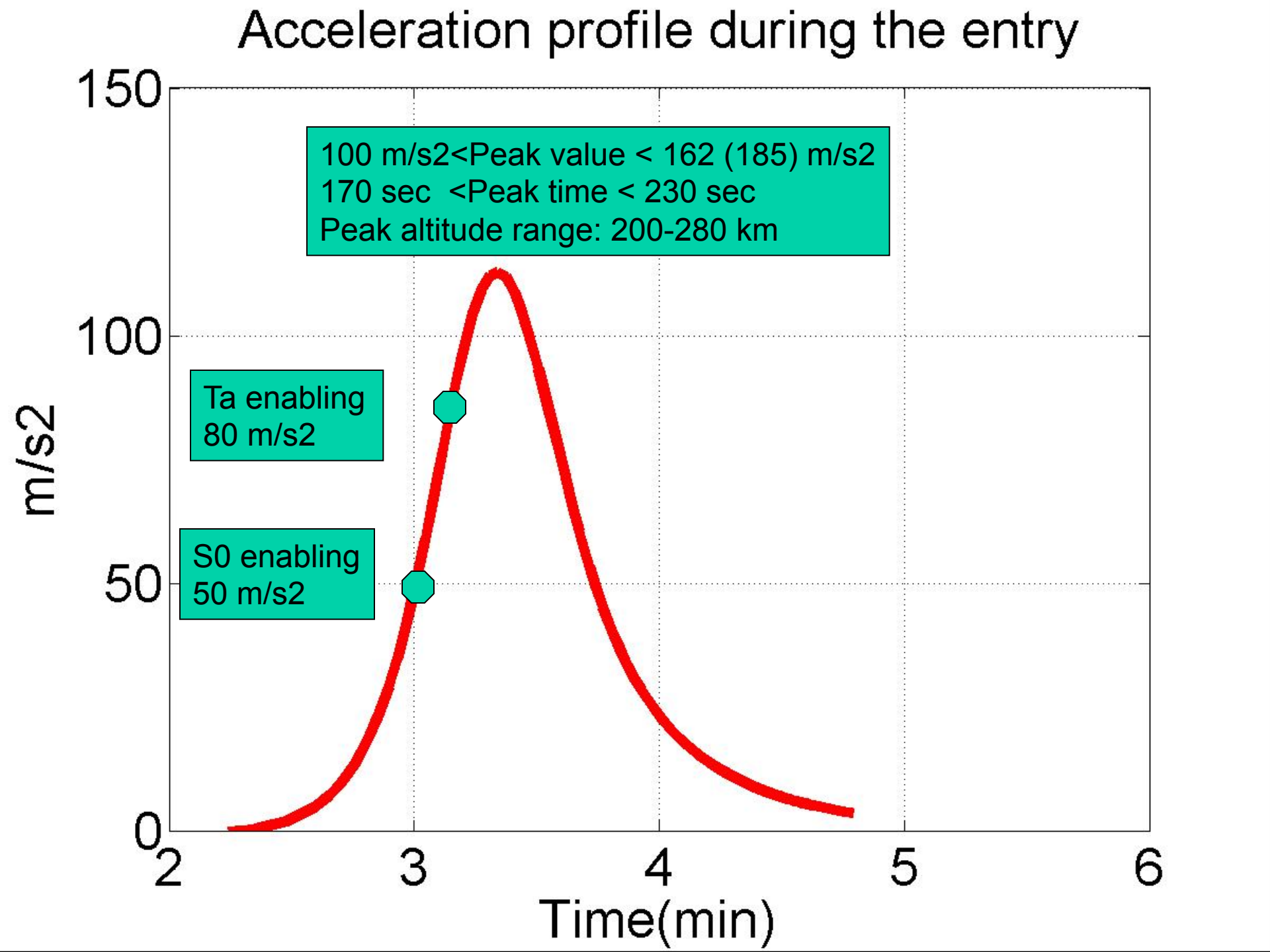
Conclusions

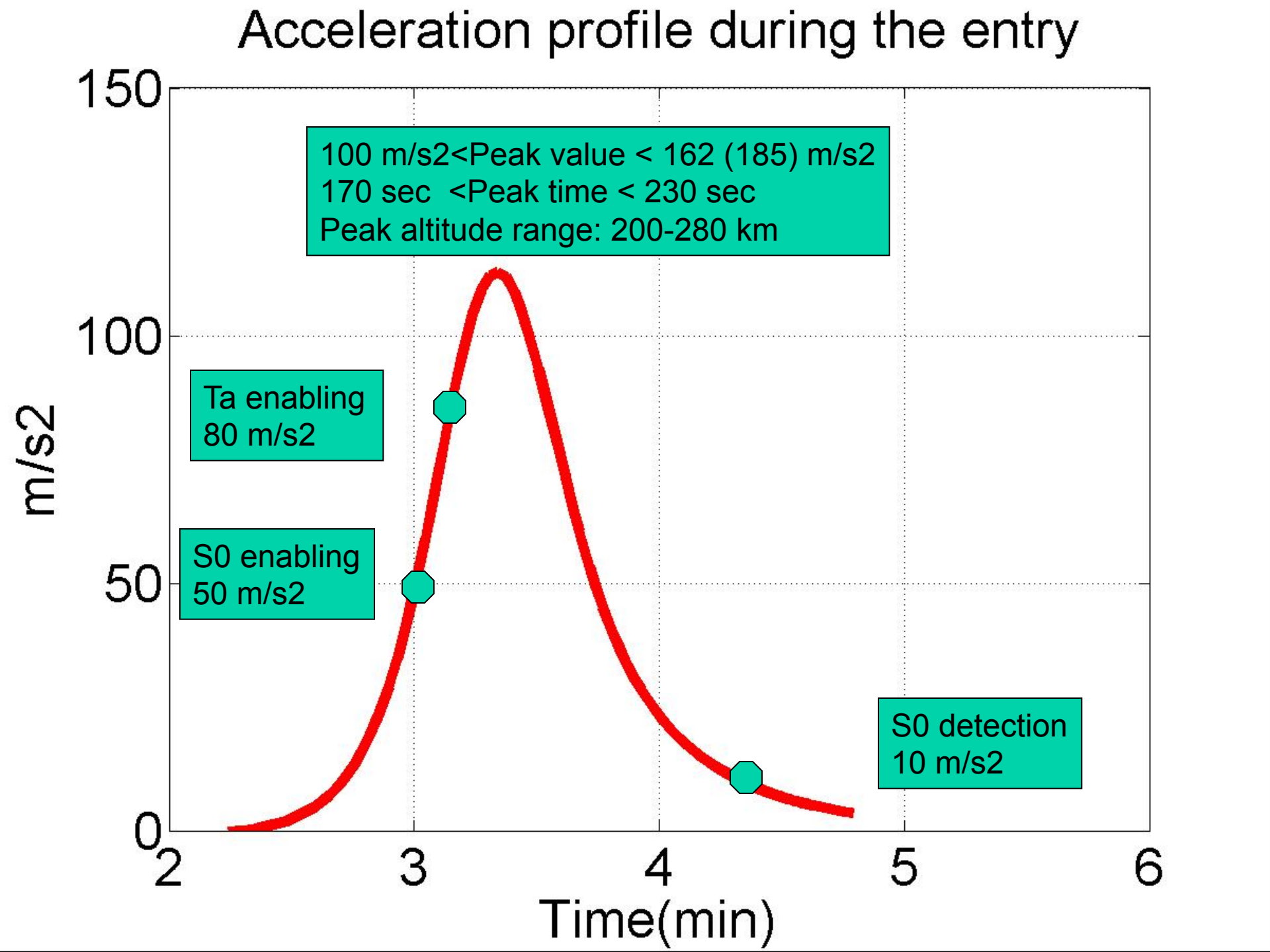
- Probe/Orbiter synergy approach to explore Titan
- Titan atmosphere seems to be well within Yelle envelope
- Some Huygens open issues in work; closure expected by early October. Possible outcome:
  - Baseline mission confirmed; target for entry at -65 º ± 3°
  - Adjust entry angle (-64 º ± 3°) or (-66 º ± 3°)
  - Delayed released on Tc (by up to 10 days ?) allows to reduce entry corridor but risks ; benefits not quantified
- Two contingency scenarios identified with probe release on later orbit: Overall mission impacts are high
- Look forward to PWS#3 !!

- Back-up material

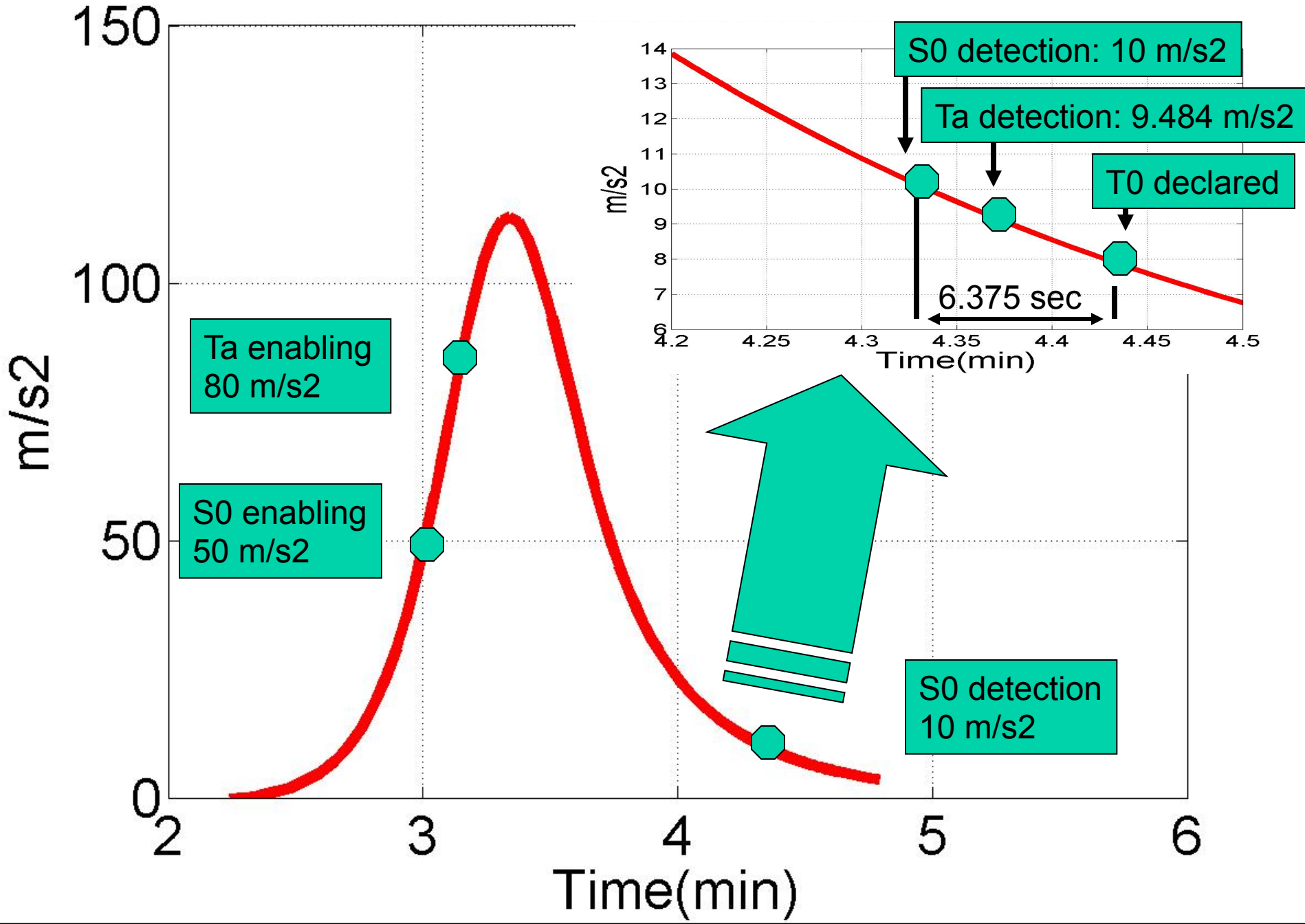

Acceleration profile during the entry
100 m/s2<Peak value < 162 (185) m/s2
170 sec <Peak time < 230 sec
Peak altitude range: 200-280 km
150
100
50
0
m/s2
2
3
4
5
6
Time(min)


Acceleration profile during the entry
150
100
50
0
m/s2
100 m/s2<Peak value < 162 (185) m/s2
170 sec <Peak time < 230 sec
Peak altitude range: 200-280 km
S0 enabling
50 m/s2
2
3
4
5
6
Time(min)

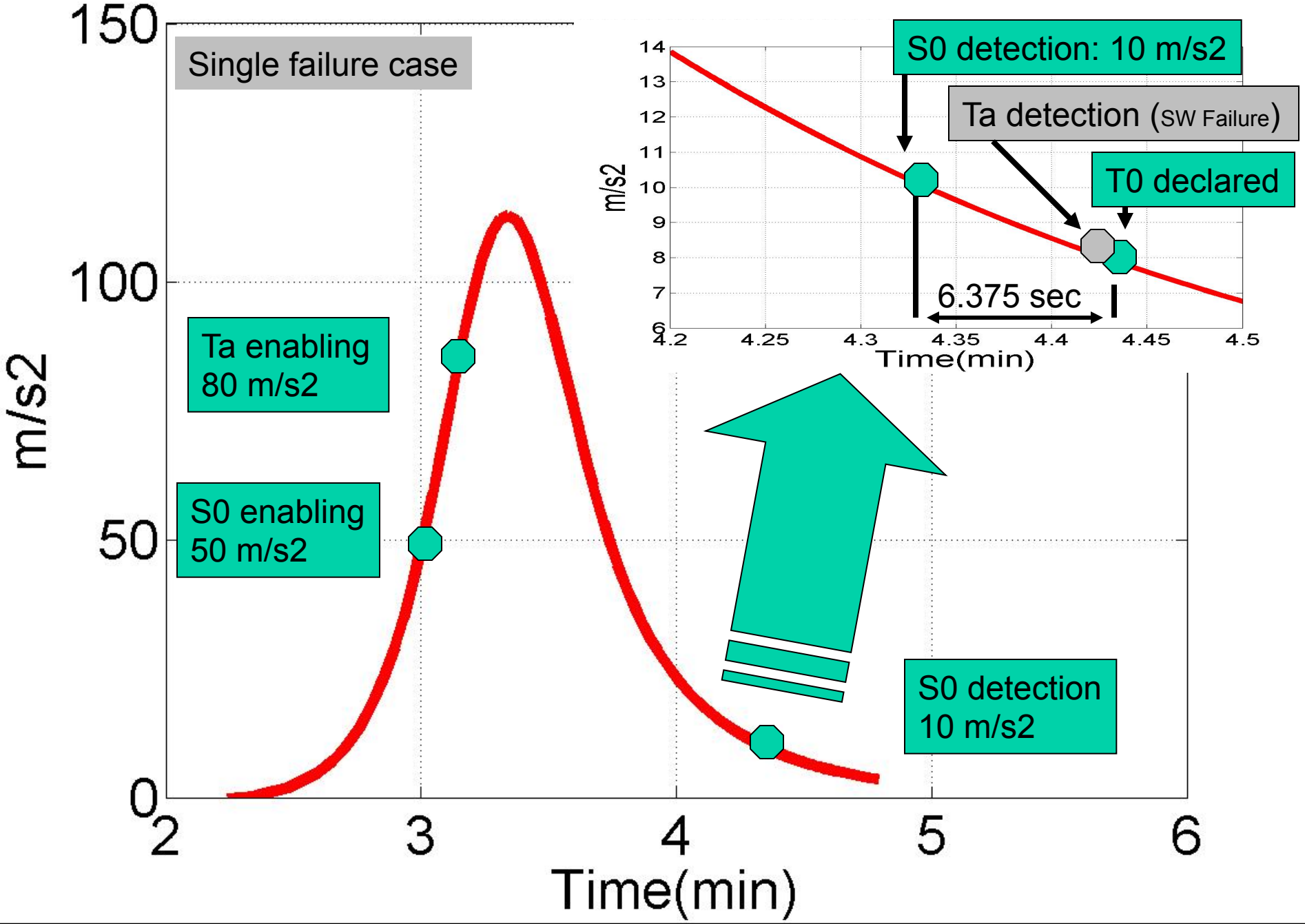

Acceleration profile during the entry
100 m/s2<Peak value < 162 (185) m/s2
170 sec <Peak time < 230 sec
Peak altitude range: 200-280 km
Ta enabling
80 m/s2
S0 enabling
50 m/s2
150
100
50
0
m/s2
2
3
4
5
6
Time(min)


Acceleration profile during the entry
150
100
50
0
m/s2
100 m/s2<Peak value < 162 (185) m/s2
170 sec <Peak time < 230 sec
Peak altitude range: 200-280 km
Ta enabling
80 m/s2
S0 enabling
50 m/s2
S0 detection
10 m/s2
2
3
4
5
6
Time(min)

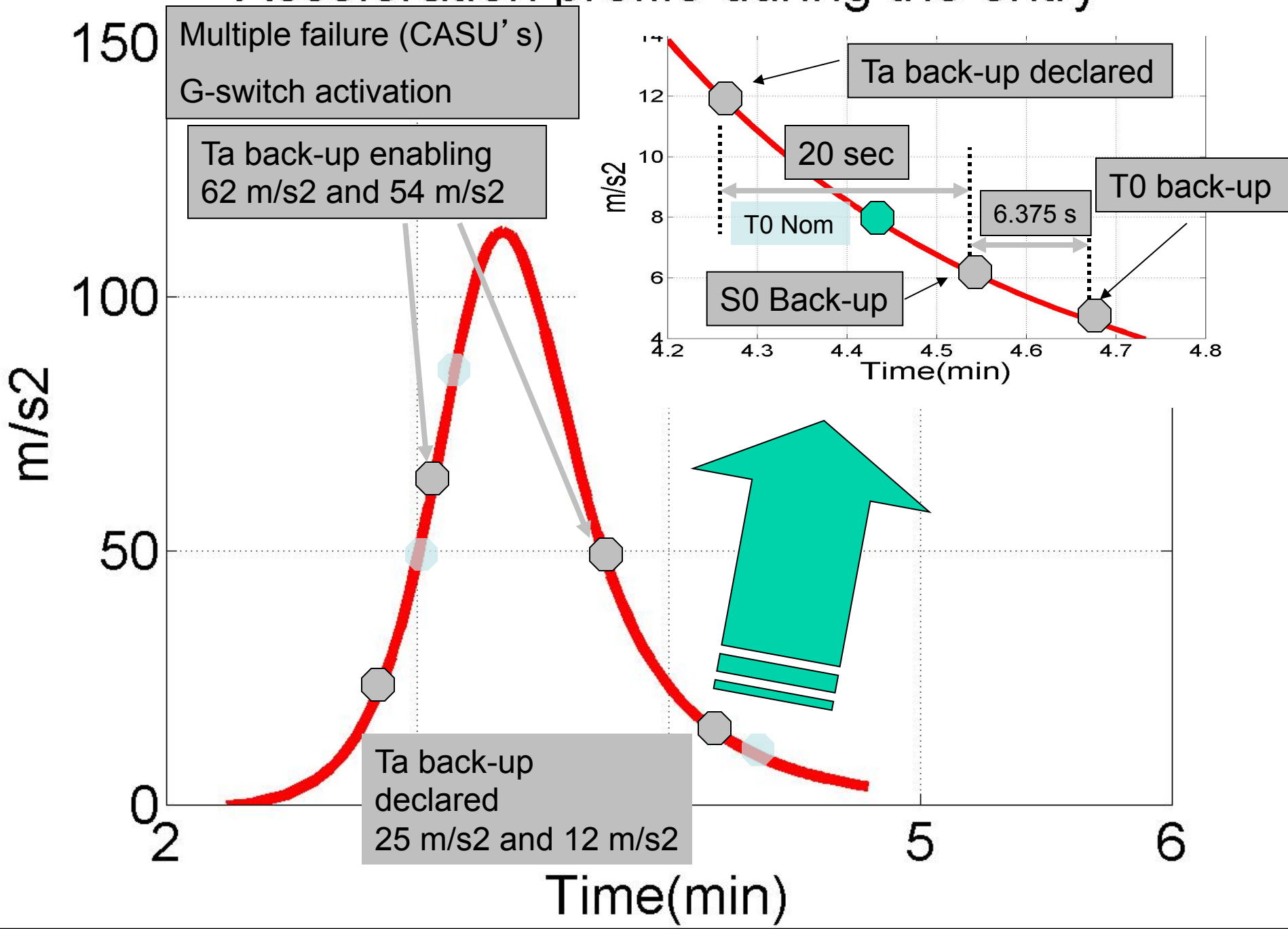
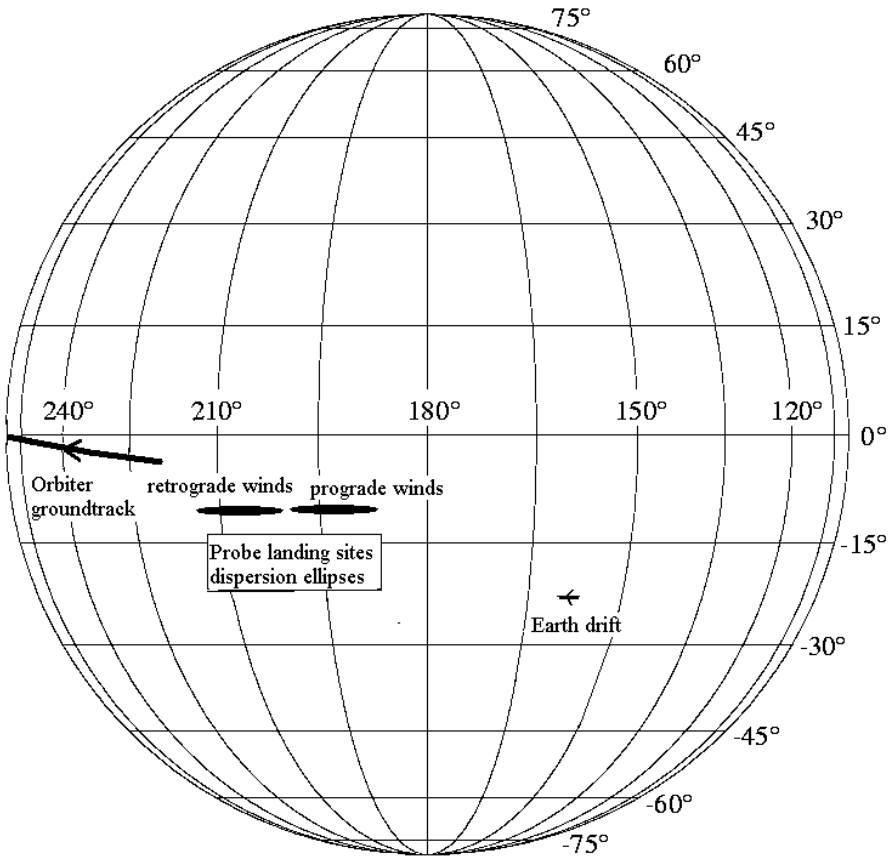
Acceleration profile during the entry



Acceleration profile during the entry



Acceleration profile during the entry



Zonal wind effects