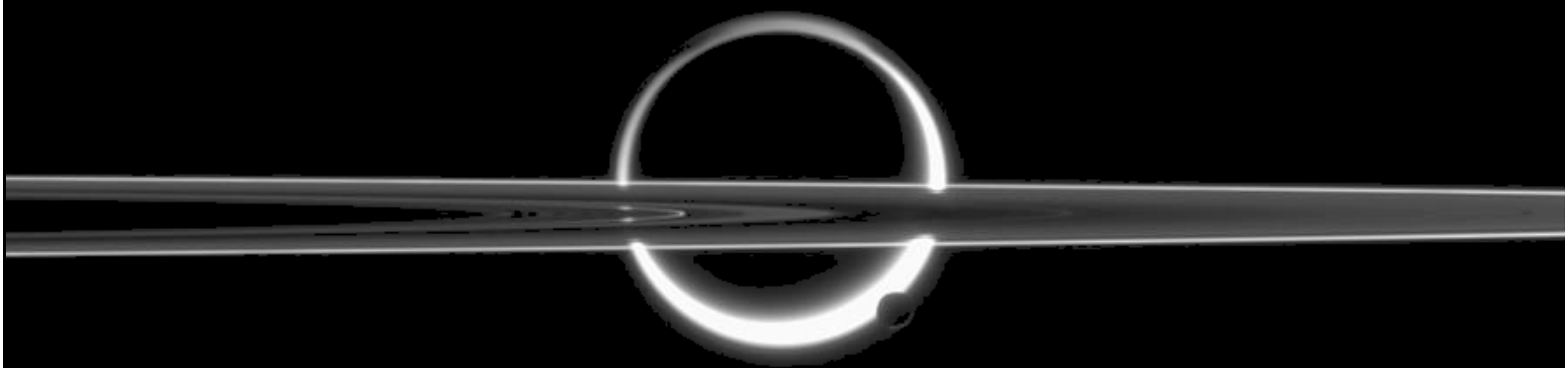
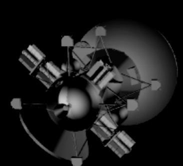
Titan Saturn System Mission
In Situ Element



Presentation at OPFM Instrument Workshop



Presented by Christian Erd

June 3, 2008

European Space Agency, ESA/ESTEC, Noordwijk

Outline

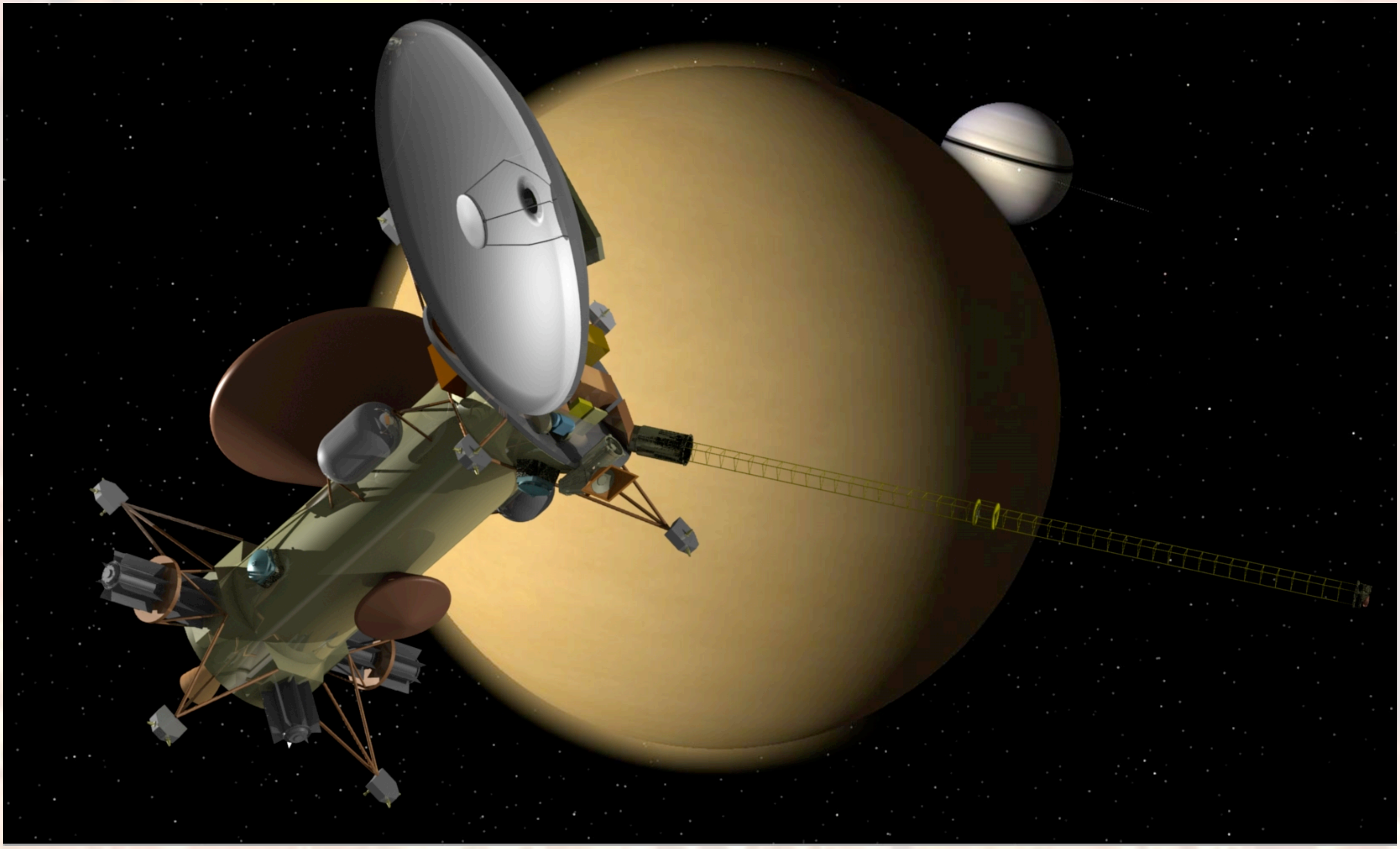
- Introduction
- Mission architecture
- Mission profile
- Environment and payload constraints
- Model payload
- Planning and outlook

Introduction

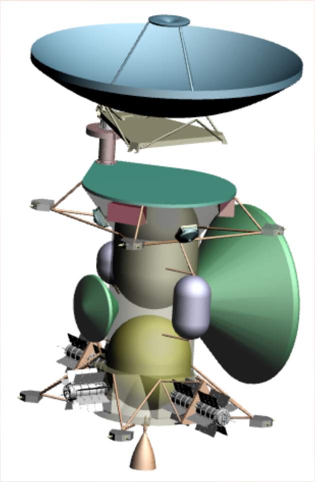
- Joint project with NASA
  - The decision between the two outer planet projects will be taken jointly (NASA & ESA)
- Status of ESA study
  - ESA has been preparing the technical study of the in-situ elements for a few months
- All contents of this presentation is very preliminary and subject to change
- Detailed assessment of system to start in 11 June

Mission Architecture

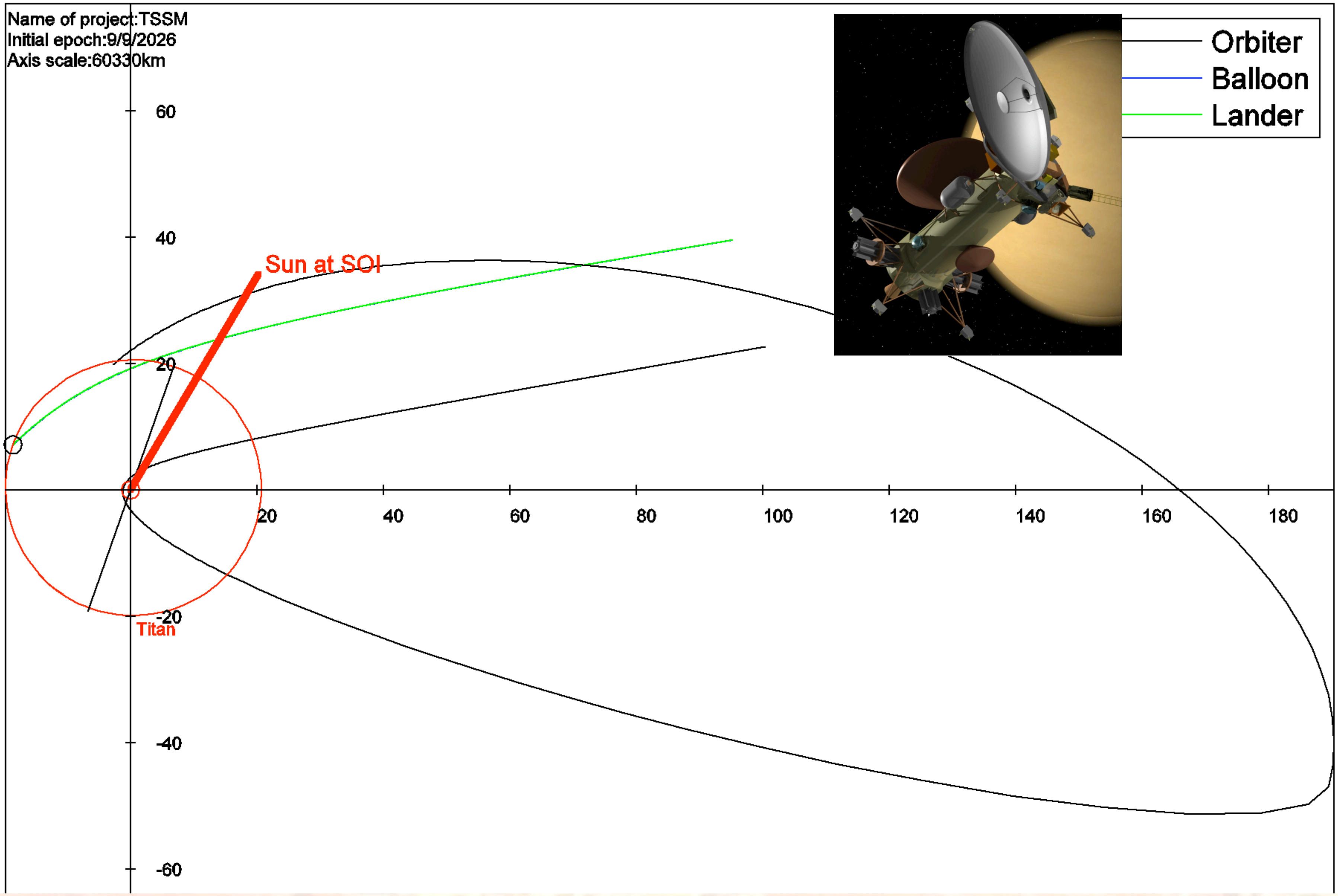
- Two in-situ elements included in reference mission
  - Montgolfière
  - Atmospheric probe/lander (two options to be studied)
- Both in-situ elements carried by NASA spacecraft to Saturn
- No autonomous flight control of in-situ elements
- Heat-shield for atmospheric entry
- Parachutes for descent and hot air balloon for Montgolfière
- Power by MMRTG (Montgolfière) and ASRG (Probe)



Baseline Mission Profile

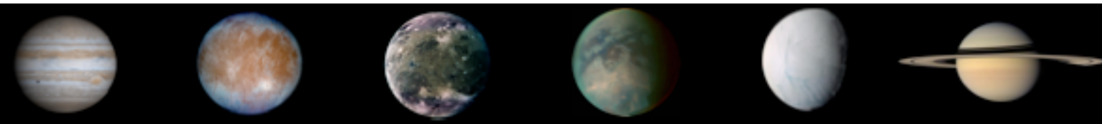


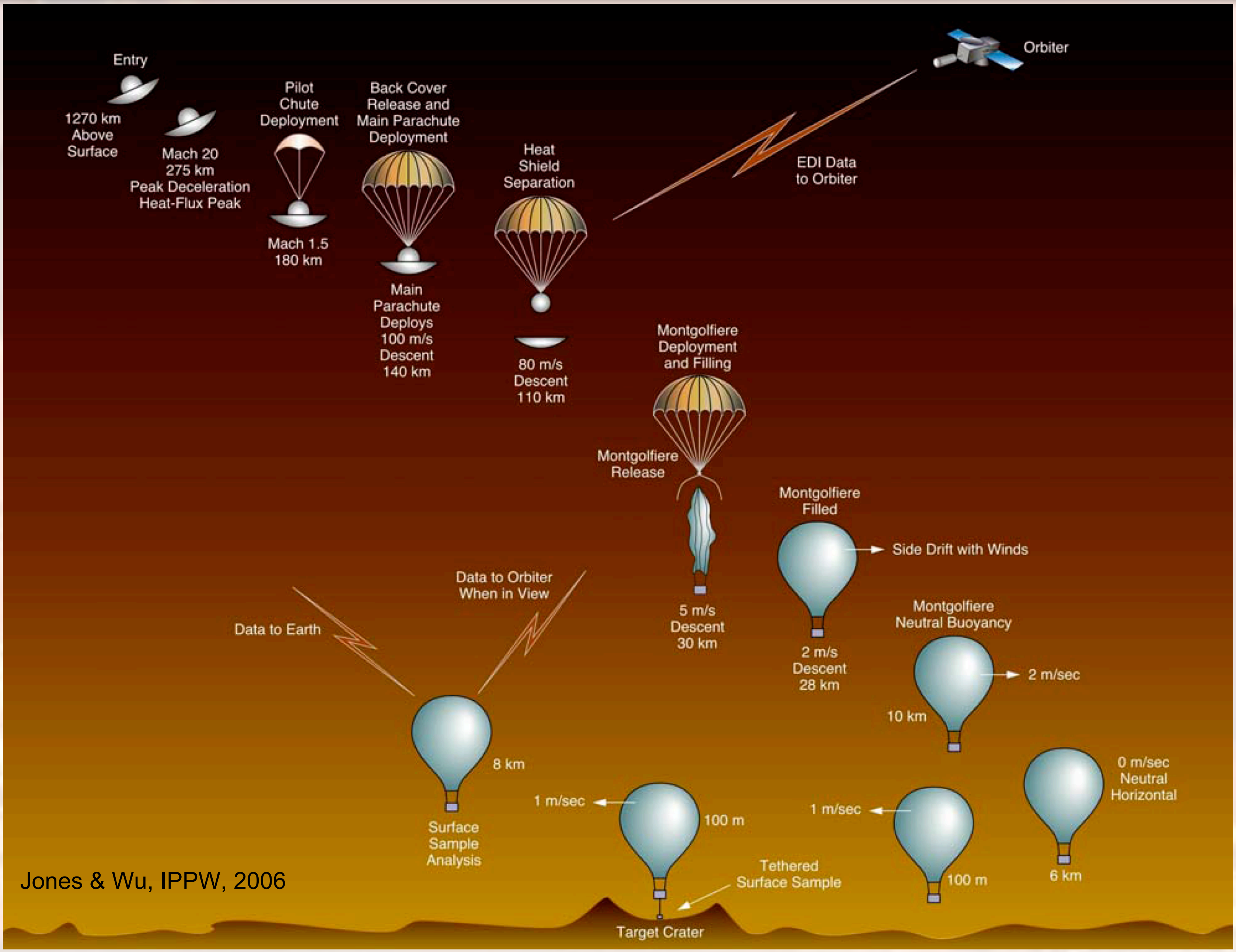
- Launch on Atlas V with VEEGA sequence to Saturn
- ESA Baseline: launch in 2018
- 10 yr transfer to Saturn by NASA orbiter s/c
- Release prior to Saturn orbit injection from orbiter
  - Both Montgolfière and Probe/lander
- About 5 months ballistic flight to Titan
- Arrival mid-latitudes (4°S to 58°N) or polar (N)


Name of project:TSSM
Initial epoch:9/9/2026
Axis scale:60330km
Orbiter
Balloon
Lander
Sun at SOI
Titan
60
40
20
-20
-40
-60
20
40
60
80
100
120
140
160
180

Entry and Descent

- Entry in Huygens type scenario
- Breaking with aero-shell
- Two parachutes
- Montgolfière fills balloon during slow phase of descent



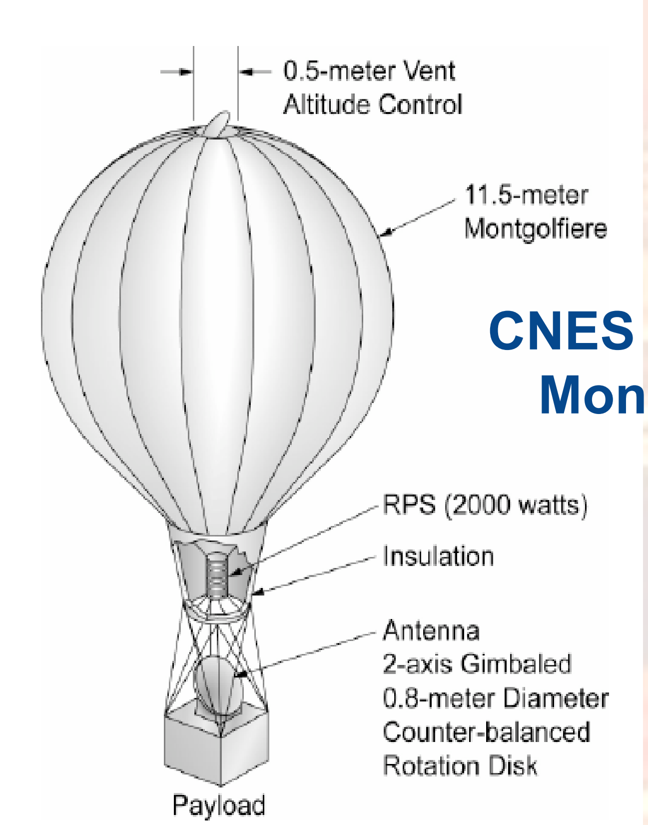


Jones & Wu, IPPW, 2006

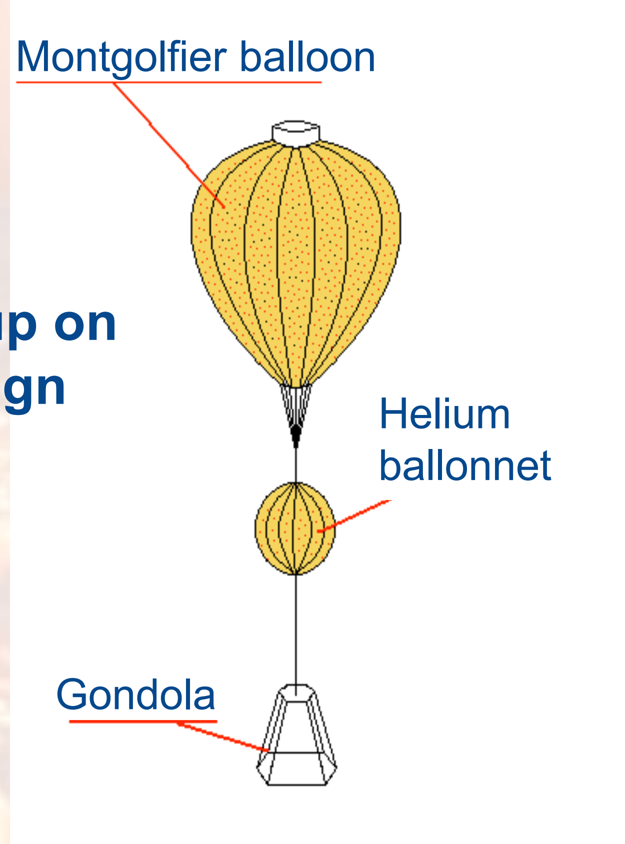
Data Downlink

- Baseline downlink via orbiter as relay satellite
- Data rate dependent on distance
  - Limited data rate for about 1.5 years after entry (few 100 bps)
  - After arrival of orbiter at Titan expect up to 10 kbps
  - Dependent on overall power – possibly interleaved with instrument operations
  - Short duration relay with orbiter during descent and landing (typically 3-5 hours)

Montgolfier Design Options



CNES – JPL Working Group on Montgolfier Balloon design

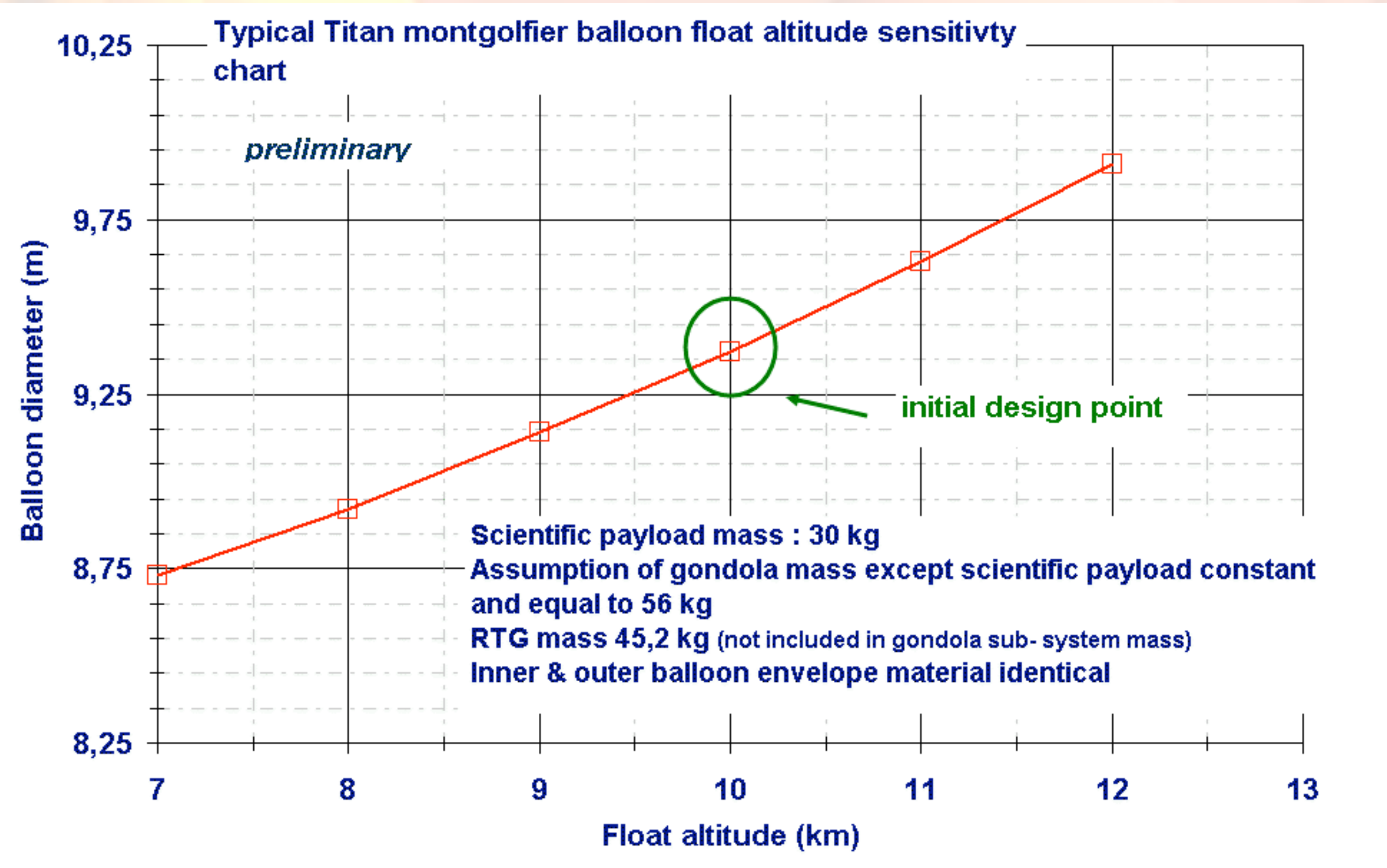


Double wall montgolfier design by JPL

[Ref. 1]: Jack A. Jones, James A. Cutts, Jeffery L. Hall, Jiunn-Jenq Wu, Debora Ann Fairbrother, and Tim Lachenmeier, "Montgolfiere Balloon Missions for Mars and Titan," *IPPW*, Athens, Greece, June 2006.

Single wall montgolfier with additional He ballonnet to secure the descent by CNES

Montgolfière Performance

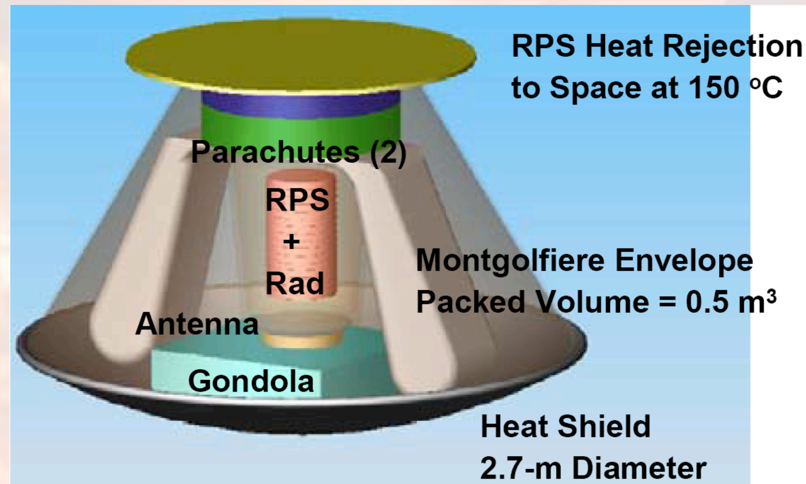


Baseline Mission Profile

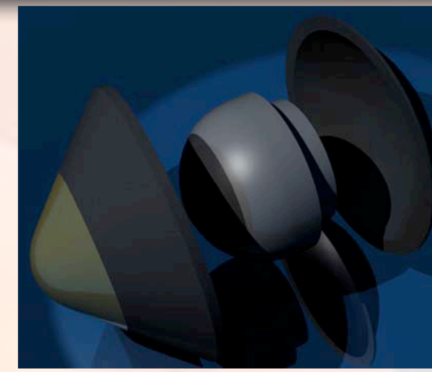
	Montgolfière	Probe/lander 1	Probe/lander 2
Total power available	100 W (MMRTG)	140 W (ASRG)	Battery
Lifetime	6 months goal: 1 yr	>2 Ti-days (32 d) goal: 4 Ti-days	2 – 3 hours
Operational altitude	Descent, 10^{+2}_{-4} km near surface, landing	During descent, On surface	During descent, On surface
Payload (very preliminary)	30 kg, 50 W	15 kg, 90 W	15 kg, 50 W

Environment – Important for Instrumentation

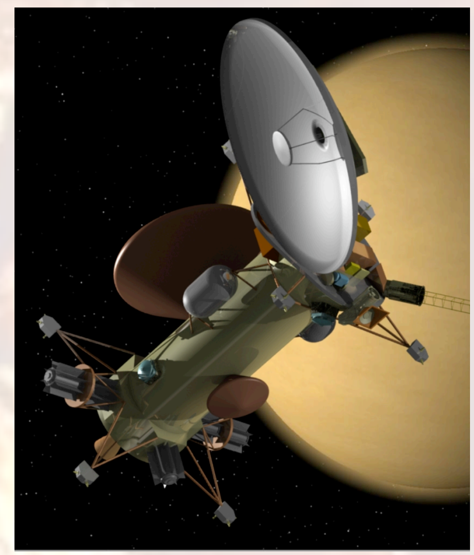
- Total mission dose: 20 krad
- In-situ elements will be in dense atmospheric environment
  - Ambient temperature (80 - 95°K)
    - conductive cooling
  - Possible humidity
    - condensation e.g. on apertures



Payload Constraints



- About 10 years interplanetary transfer
- Accommodation inside aero-shell together with MMRTG / ASRG
  - Thermal and radiation issues
- Limited payload operations foreseen during cruise
  - Limited measurement possibilities
- Large thermal variations
  - Venus fly-by
  - Ballistic coast after separation: 5 months in outer space
  - Entry and Titan atmosphere
- In-situ operations likely limited by power and telemetry
  - Clever data selection prior to transmission
  - Low power implementations and interleaved operations



Overview of Model Payload

- Model payload defined to fulfil science requirements
- Need technical instrument specifications to allow for system study in more detail
- Resource requirements collected per instrument
  - Accommodation: mass, power, size, FOV, heating/cooling, etc
  - Operations: telemetry , total data amount, duty cycle

Overview of *In-Situ* Element's Payload

Montgolfière	Long lived Lander	Short lived Lander
Nadir and stereo cameras	Camera, IR spectrometer, radiometer	
Imaging spectrometer		
Chemical analyzer	Chemical analyzer	
Atmospheric Structure/Meteorological	Atmospheric Structure/Meteorological	
Electric environment	Electric environment	
Radar sounder	—	
Radio-science	Radio-science	
Magnetometer	Magnetometer	
Nephelometer	Acoustic sensor	
—	Telescopic Raman Spectrometer	
—	Seismometer	—
—	Microscope	—
—	Mole	—
—	XRF/XRD	—
—	Water extractor	—

The *in-situ* elements of TSSM (I)

- Montgolfière (hot air balloon, floating)
  - Height 10 km (6 – 12 km), near surface operation optional
  - Payload complement currently ~40 kg, 75 W
  - Lifetime min. 6 months, goal 1 year

The *in-situ* elements of TSSM (I)

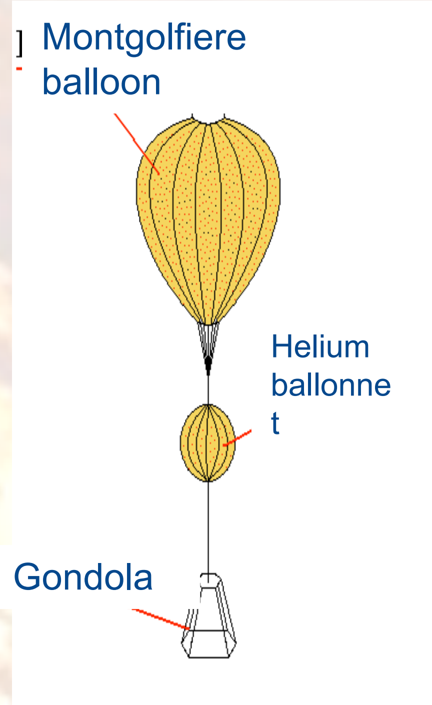
Table 1 Instrument interface summary for gondola core payload elements.

Instrument	*Acronym*	*Mass [kg]*	*Size [cm]*	*Power [W]*	*TM [kbps]*
Stereo Camera (s)	VISTA-M	2	TBD	6	TBD
Titan Montgolfiere Chemical Analyser (1 or 2)	TMCA(1 or 2)	16 or 11	50x40x20	40 or 35	5
Balloon Imaging Spectrometer	BIS	2.3 (1kg opt. head, 1.3 kg electronics)	26x24x15 (opt. head) 20x30x10 (electronics)	10	740
Atmosph. Structure Instrument /Meteorological Package	ASI/MET	~ 1	~20x20x20	~5	~0.150
Titan Electric Environment Package – Balloon	TEEP-B	0.3 – 0.95	Electroncs: 10×10×2 Plus antenna	1	TBD
Titan Radar Sounder	TRS	8 – 12	37x25x13	15-25	
Montgolfiere Radio Science Transmitter	MRST	1	TBD	TBD	TBD (very low)
Magnetometer (Option 1)	MAG	0.5	Each sensor: 11 x 7 x 5	1.5	0.8

Table 2 Instrument interface summary for gondola replacement payload elements

Instrument	*Acronym*	*Mass [kg]*	*Size [cm]*	*Power [W]*	*TM [kbps]*
Titan Montgolfiere Chemical Analyser (4)	TMCA(4)	5	35x25x15	25	5
Titan Altimeter and Lake Penetrating Radar	TALPR	5 – 7	30x30x30	10-25	
Nephelometer	SPEX	< 5 (tbc)	13x13x6	< 3 W (tbc)	10 (tbc)

Strawman payload for the Montgolfière



Model *Core* Payload Montgolfière (I)

- Visible Imaging System (VISTA-M), 2 kg, 6 W
- Stereo wide angle imaging and narrow angle high resolution camera
  - ±20° stereo and 60° side-looking
  - High resolution nadir

- Balloon Imaging Spectrometer (BIS), 2.3 kg, 10 W
  - Telescope with diffraction grating spectrometer, 2-5 μm

- Titan Montgolfière Chemical Analyzer (TMCA), 11–16 kg, 35 W
  - GC/MS, stable isotope MS, amino acid analyzer, wet chemistry, atmospheric laser desorption/ionisation, aerosol collector

- Magnetometer (MAG), 0.5 kg, 1.5 W
  - Two fluxgate sensors preferably on boom, +/- 1024 nT, 32 pT resolution

Model *Core* Payload Montgolfière (II)

- Radar Altimeter and Subsurface Radar (TRS), 12 kg, 25 W
  - altimetry and subsurface profiles
- Montgolfière Radio Science Transmitter (MRST), 1kg, TBD W
  - UHF transmitter (use of USO), carrier and ranging signal to orbiter and Earth (VLBI measurements)
- Atmospheric Structure/Meteorological Package (ASI/MET), 1 kg, 5 W
  - Accelerometer, barometer, thermometer (+ microphones?)
- Titan Electric Environment Package (TEEP), 1 kg, 1 W
  - Vertical and horizontal electric field, electric conductivity, acoustic turbulences, ELF-VLF magnetic component

Model *Alternative* Payload Montgolfière

- Titan Montgolfière Chemical Analyzer (TMCA), 5 kg, 25 W
  - light version compared to core P/L
- Titan Altimeter and Lake Penetrating Radar (TALPR), 7 kg, 25 W
- Spectropolarimeter for Planetary Exploration (SPEX), 5 kg, 3 W
  - Nephelometer that measures aerosol particles and their microphysical properties

The *in-situ* elements of TSSM (II)

- Lander 1 (long-lived, equatorial to low latitude, possibly dunes)
  - Descent by parachute, 2 – 3 hours
  - Surface operations min. 2 Titan days
  - Payload complement ~17 kg, 90 W

- Lander 2 (short-lived, northern latitude, sea/lake landing)
  - Descent by parachute, 2 – 3 hours
  - Floating for 1 hour
  - Payload complement ~14 kg, 75 W

The *in-situ* elements of TSSM (II)

Preliminary strawman payload on probe/lander 1, long-lived, dry landing

Table 1 Instrument interface summary for lander 1 core payload elements.

Instrument	*Acronym*	*Mass [kg]*	*Size [cm]*	*Power [W]*	*TM [kbps]*
Titan Lander Chemical Analyser (4)	TLCA(4)	5	35x25x15	25	5
Lander Radio Science Transponder	LRST	2	TBD	20 (TBC)	TBD (very low)
Titan Probe Imager Radiometer Spectrometer	TIPIRS	4.9	20x20x10 for the spectrometer	24 (44)	10
Titan Regolith Subsurface Mole for Physical Properties	TiReS	1.7	35x35x12	17	30 Mbits;
Titan Electric Environment Package – Lander	TEEP-L	0.5	10 (electronics) ([1])	0.5	TBD
Acoustic Sensor Package	ACU	0.50	TBD	0.8	1kbps
Atmospheric Structure Instrument /Meteorological Package	ASI/MET	~ 1	~20x20x20	~5	~0.150
Magnetometer (Option 2)	MAG	0.3	Each sensor: 11 x 7 x 5	0.6	
Microscopic/close-up imager	MCI	0.3 (w/o DPU)	5x5x10	<5.5 (tbc)	tbd
Seismometer	SETI	1.1	9x9x9 (sensor) 10x15x5 (electronics)	0.1	2 Mbits/day

Table 2 Instrument interface summary for lander 1 replacement payload elements

Instrument	*Acronym*	*Mass [kg]*	*Size [cm]*	*Power [W]*	*TM [kbps]*
Icy Mineralogy Package (XRD/XRF) - reflection version	IMP-reflection	0.150 kg	500 cm^3	4.8 W	min 3.6 kb per sample
Icy Mineralogy Package (XRD/XRF) - transmission version	IMP-transmission	0.270 kg	900 cm^3	7.2 W	min 3.6 kb per sample
Raman Spectrometer for Titan Remote Observation	RETRO	2.1	- Spectrometer: 15x15x10	<10	1,024 (in a nominal scenario)
Sub critical water extractor & capillary eletrophoresis	tbd	tbd	tbd	tbd	TBD

Long-lived dry-landing Probe

Model *Core* Payload (I)

- Titan Lander Chemical Analyzer (TLCA), 5 kg, 25 W
  - light version compared to core P/L on Montgolfière
- Titan Probe Imager Radiometer Spectrometer (TIPIRS), 4.9 kg, 24 W
  - Narrow/wide angle cameras, IR grating spectrometer, surface lamp
- Atmospheric Structure/Meteorological Package (ASI/MET), 1 kg, 5 W
  - Accelerometer, barometer, thermometer (+ microphones)
- Titan Electric Environment Package (TEEP-L), 0.5 kg, 0.5 W
  - Vertical/horizontal electric field, electric conductivity, permittivity and acoustic turbulences
- Seismometer (SETI), 1.1 kg, 0.1 W
  - Various concepts, record of global seismic activity

Long-lived dry-landing Probe

Model *Core* Payload(II)

- Lander Radio Science Transponder (LRST), 2 kg, 20 W
  - Two way link to Earth, Doppler and ranging measurement
- Magnetometer (MAG-L), 0.3 kg, 0.6 W
  - magnetoresistive sensors, boom location preferred
- Acoustic Sensor and liquid science package (ACU), 1 kg, 0.8 W
  - acoustic sensors and “drizzle” detector
- Microscope/close-up imager, MIC (0.3 kg, 5.5 W)
  - Camera (450–850 nm) spectral range with LED’s including UV fluorescence measurements
- Titan Regolith Subsurface Mole for Physical Properties TiReS, (1.7 kg, 17 W)
  - Tethered payload carrier with a penetration depth down to several meters, measures thermo-physical and electric properties of the soil

Long-lived dry-landing Probe

Model *Alternative* Payload

- Telescopic Raman Spectrometer (RETRO), 2 kg, 10 W
- XRF/XRD instrument, 0.5 kg, 4.8 W
- Sub-critical water extractor & capillary electrophoresis, 3.8 kg, 20 W

The *in-situ* elements of TSSM (II)

Preliminary strawman payload on probe/lander 2, short-lived, wet landing

Table 1 Instrument interface summary for lander 1 core payload elements.

Instrument	*Acronym*	*Mass [kg]*	*Size [cm]*	*Power [W]*	*TM [kbps]*
Titan Lander Chemical Analyser (4)	TLCA(4)	5	35x25x15	25	5
Lander Radio Science Transponder	LRST	2	TBD	20 (TBC)	TBD (very low)
Titan Probe Imager Radiometer Spectrometer	TIPIRS	4.9	20x20x10 for the spectrometer	24 (44)	10
Titan Electric Environment Package – Lander	TEEP-L	0.5	10 (electronics)	0.5	TBD
Acoustic Sensor Package	ACU	0.50	TBD	0.8	1kbps
Atmospheric Structure Instrument /Meteorological Package	ASI/MET	~ 1	~20x20x20	~5	~0.150
Magnetometer (Option 2)	MAG	0.3	Each sensor: 11 x 7 x 5	0.6	

Table 2 Instrument interface summary for lander 1 replacement payload elements

Instrument	*Acronym*	*Mass [kg]*	*Size [cm]*	*Power [W]*	*TM [kbps]*
Microprobe Mass Spectrometer	Mini-MS	0.3	3x3x10	2	5
Raman Spectrometer for Titan Remote Observation	RETRO	2.1	- Spectrometer: 15x15x10	<10	1,024 (in a nominal scenario)

Short-lived wet-landing Probe Model Core Payload (I)

- Same instruments as for long-lived probe:
  - Chemical Analyzer
  - Imager Radiometer Spectrometer
  - Narrow/wide angle cameras, IR grating spectrometer, surface lamp
  - Atmospheric Structure/Meteorological Package
  - Electric Environment Package
  - Radio Science Transponder
  - Magnetometer
  - Acoustic Sensor and liquid science package

Alternative Payload

- Mini Mass Spectrometer (mini-MS), 0.3 kg, 2 W
- Telescopic Raman Spectrometer (RETRO), 2 kg, 10 W

Outlook

- ESA activities only started beginning of 2008
- Beginning with technical assessment study (11 June 2008)
- NASA & ESA will jointly decide between Jupiter & Saturn exploration (~Oct 2008)
- For the successful mission ESA starts two industrial competitive system studies in 2009 (for 1 year)

Plans on Instrument Assessment

- Through an external review ESA was requested to change approach of payload procurement
  - Assessment study of instrumentation in parallel with s/c assessment study
  - Earlier definition of interfaces and resource requirements
  - Earlier start of instrument activity
- ESA will issue call for instrument assessment studies earlier than usual (~2009, TBC)
- AO for instrumentation together with s/c definition phase (~2011, TBC)

Planning and Outlook

11 June – 16 July 2008	ESA CDF study
15 July 2008	Input to JPL study report
September 2008	ESA study report
Oct./Nov. 2008	Joint decision NASA-ESA between Jupiter & Saturn exploration
Q1/2009	Industrial system assessment study
Q2/2009	Instrument assessment studies
2018	Launch

Summary

- In-situ mission combined with orbiter mission
- Two *in-situ* possibilities: Montgolfière and probe/lander
- Both constrained by power and telemetry
- Model payload defined for initial phase of system assessment study
- Mission assessment is starting to aid selection between Jupiter and Saturn missions
- If selected industrial assessment in 2009 (1 year)
- Start of payload assessment expected in parallel (2009)