TiNet - A Concept Study for a Titan Geophysical Network

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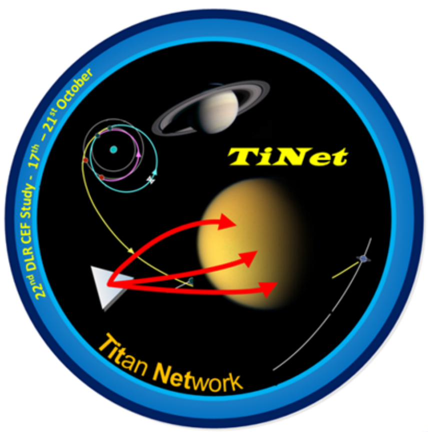

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Study Overview

- Context: HGF Alliance for Planetary Evolution and Life
  - Assess the potential for emergence and evolution of life on a planetary body
  - Concept Car missions to answer the relevant scientific questions
  - Go beyond the current NASA and ESA planning (low importance of cost and politics considerations)
- Why a geophysical network on Titan?
  - Big research theme: interior of planetary bodies, and the interaction of interior-surface-atmosphere
  - Titan due to its concurrent similarity with icy satellites as well as terrestrial planets + its uniqueness with regard to its surface conditions, atmosphere, interior is a key to increase the understanding of this topic
- How it was done:
  - CE-Study at the DLR Concurrent Engineering Facility performed in October 2012 + Postprocessing ongoing

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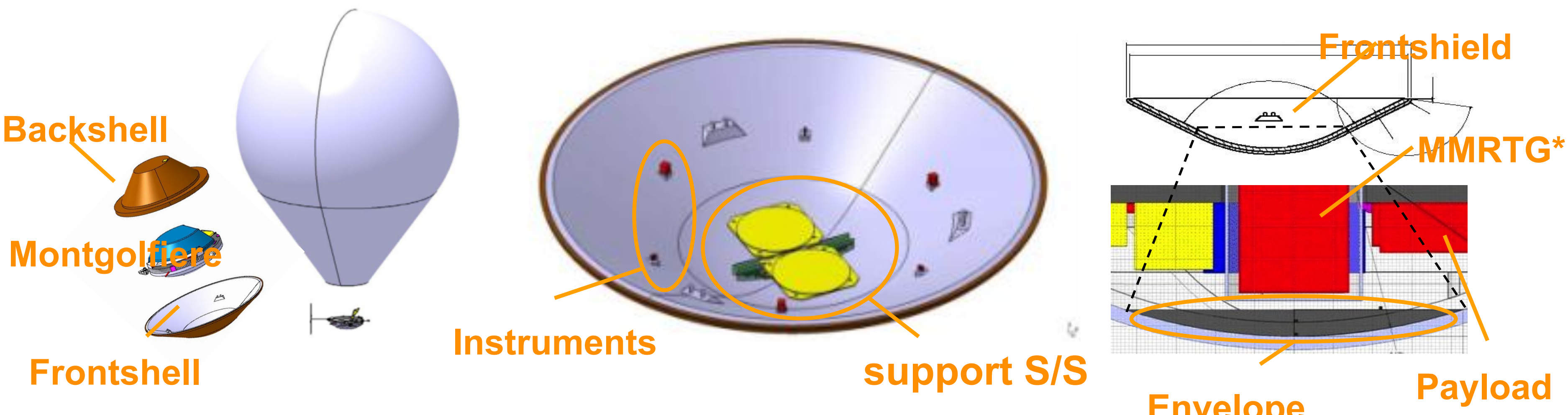
Geosaucer – a mission scenario to learn from…

- Titan Geophysics Package aka „Geosaucer“ → feasibility study (2008) in the frame of the NASA/ESA TSSM (Titan Saturn System Mission) study



- 14 kg instruments and support package accommodated in Montgolfiere heat shield
- Instruments: magnetometer, seismometer, radio science
- X-band communication with patch antennas
- RTG + secondary batteries

*Multi-Mission RTG

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Scientific Objectives

- Measure tidally induced surface displacements + forced librations of outer ice shell
- Measure time-variable magnetic field (induced and inducing) to determine location and thickness of internal ocean
- Measure the level of seismic activity; determine the structure of outer ice shell and deduce clues on internal ocean
- Measure regolith properties
- Measure atmospheric composition
- Optional: Determine the Titan lake composition

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Science Traceability Matrix

Science Objective	Measurement	Instrument	Priority
Pressure, Temperature, Winds	Pressure, temperature, winds	In-situ MET station	Mid
Atmospheric composition	Chemical constituents and isotopic compositions	GC/MS	Mid
N_2, NH_3, CH_4, CO origins	Isotopic ratios	GC/MS	High
H_2O and CH_4 abundances	Humidity measurements	Humidity sensor	Low
Regolith chemical properties	Organic fallout speciation	Raman spectrometer, LIBS, GC/MS	High
Regolith physical properties	Permittivity and magnetic suszeptibility	Permittivity probe	Mid
Amount of cryovolcanisms	Tribolelectric effect	Triboelectric sensors	Low
Internal differentiation of the deep interior	Tides, heat flow, seismicity, rotational state	Radio Science, Seismometer, Heat flow probe,	High
Magnetic field environment	Electrical field, induced and inducing magnetic fields, and their time rates of change	Magnetometer, permittivity probe	High
Interior composition: thickness and rigidity of ice layer; thickness, depth and electrical conductivity of liquid water ocean	Tides, seismicity, permittivity, rotational state	Radio Science, seismometer, permittivity probe	High

Mission Requirements and Constraints

- **Mission goal:**
- **The mission shall establish a network of instrumented landing units on the surface of Titan, which operate simultaneously to measure geophysical parameters of the body**
- **Mission requirements:**
  - **The mission shall be set in the 2030+ timeframe.**
  - **The mission lifetime shall be as a minimum 1 and maximum 2 Titan days.**
- **The landing sites shall fullfill the following requirements:**
  - **3 stations globally distributed are minimum for seismic measurements**
  - **Sites shall:**
    - **Be restricted to 2030+ illuminated hemisphere**
    - **Cover pole, mid-latitudes (45 deg, leading or trailing hemisphere) and equator (sub- resp. anti-saturnian hemisphere) → global dispersion**
    - **A local dispersion shall be realized with the sub-landers (3-5 sub-lander)**

System Requirements

- **The total mass of all units shall be < 320 kg (including EDL-subsystem / Thermal Protection)**
- **Functional requirements:**
    - **The landing units shall be able to land on solid surface and in liquids**
    - **The landing units (Remote units) shall be able to communicate their science and H/K data from any landing site and on-surface attitude to a relay satellite**
    - **The landing units shall conduct science experiments autonomously**
- **Performance requirements:**
    - **The landing units shall have a lifetime between 1 (T) and 2 (G) Titan days (1 Titan day = 15 Earth days)**

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Architecture Trades

Primary Flight Element	Dumb Cruise Stage	Flyby Relay	Saturn Orbiter	Titan Orbiter		
Separation Strategy	On Cruise	From Orbit				
No. Of probes	1	2	3			
Secondary Flight Element	Lighter than Air	Probe	Heavier than air			
Surface Element	Soft Lander	Lake Lander	Combined Lander	Penetrator	Hard Lander	
No. Of surface elements per probe	1	2	3	...	n	
Thermal Control	Insulation	Coatings/Paintings	MLI	RHU	Heater	...
Communication bandwidth	S-Band	VHF/UHF	X-Band			
Communication architecture	Relay	DTE				
Antenna Type	Patch	Whip	QFH			
Power Generation	Solar	Radioisotope	Fuel Cell	Unconventional		
Energy Storage	Li-polymer					

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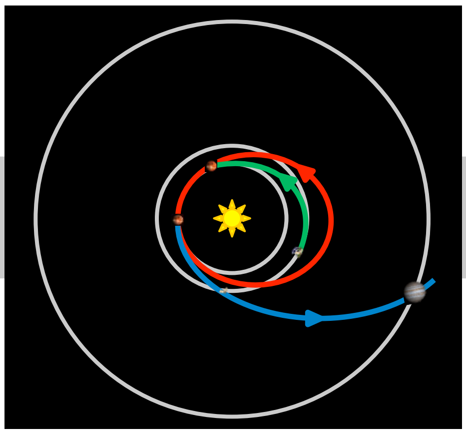
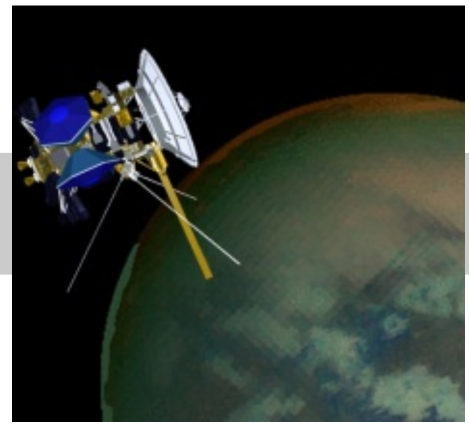
Mission Overview – 1/2

Launch in the 2030s

Inter-planetary Cruise with Swingbys



Arrival at Titan and Orbit insertion



Network Deployment, EDL and Operation

- A Cassini-size carrier transports the 3 entry probes to Titan
- Each probe enters separately and autonomously into the atmosphere, protected by a heat shield
- An additional deceleration stage (e.g. parachute) is deployed after heat shield separation.

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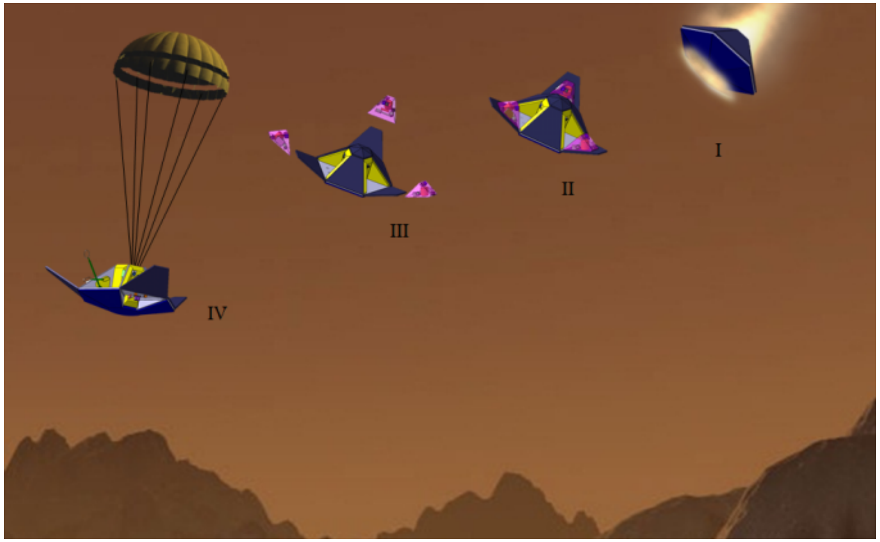
Mission Overview – 2/2



- During descent the each entry probe, later Hub (main unit) releases 3 Remote Units which are diverted by the wind, e.g. using parachutes/paraglider
- Landing on Titan surface (soil or lake)
- System start-up and beginning of measurement program
- Relay of scientific data to the carrier now functioning as an orbiter in a stable polar orbit

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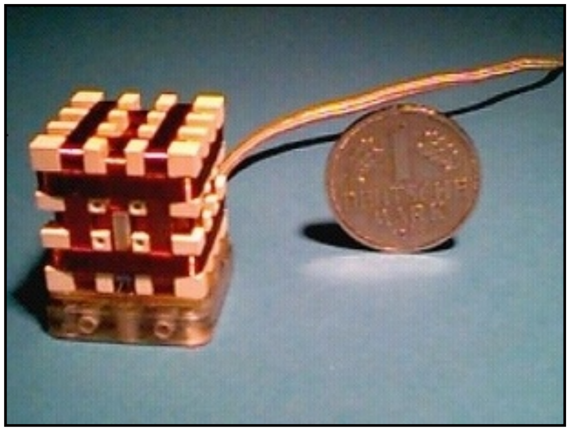
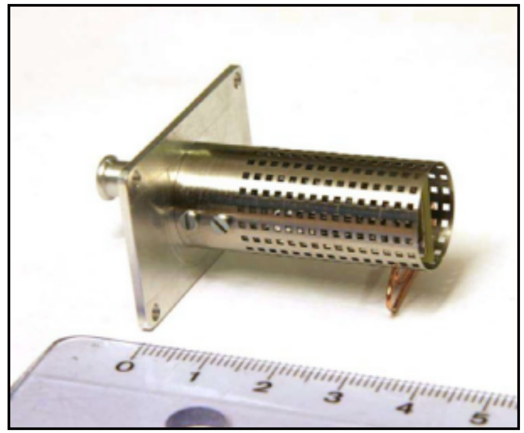
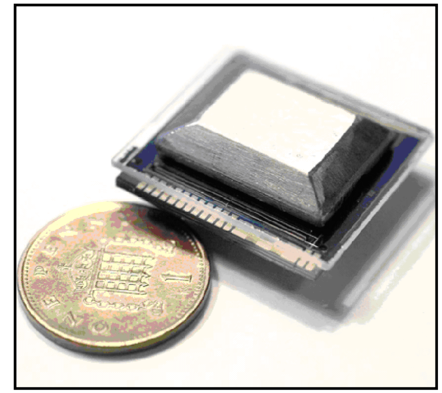
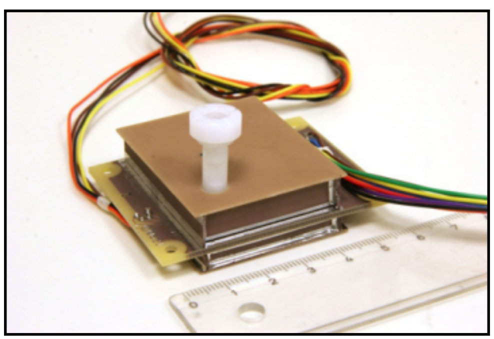
Instruments

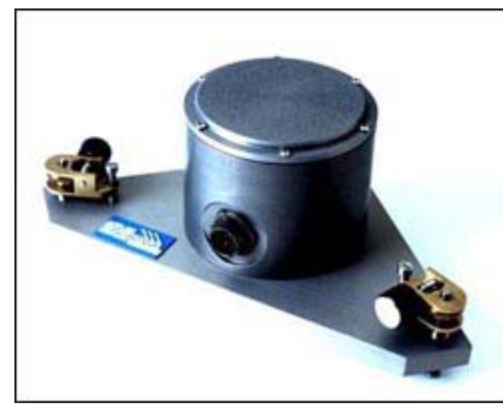








Small Instruments for geophysical measurements: (Top left) magnetometer from TU Braunschweig, proposed for Netlander; (Top right) Micro-Seismometer; (Bottom left) Pressure sensor from Mars MetNet lander; (Middle) humidity sensor (MetNet); (Bottom right) Tiltmeter (Lorenz)



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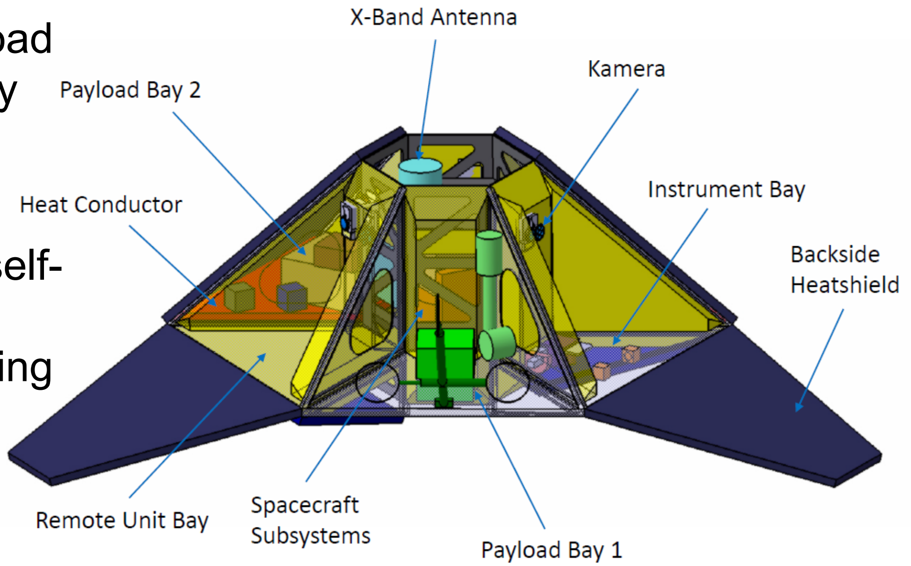
System Baseline Design - Configuration

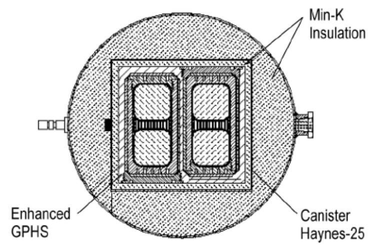
- Entry Probe:
  - Innovative sharp edged design to enhance descent stability.
  - Predefined standardized payload compartments → payload easy excheangeable
- EDL
  - Entry Probe: Passive system, self-stabilizing
  - Remote Units: Deployment during descent. Parachute for attitude stabilization only
- Hub:
  - Entry Probe reconfigured
  - Releases Remote Units
  - Passive attitude correction after landing

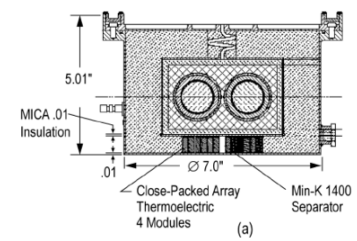


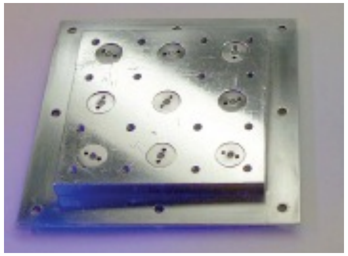
Baseline Design cont‘d

- Power
  - Hub: GPHS RTG (NASA development),
    - Pel = 19W max. / Pth = 250 W max.
  - Remote: Assumption 2/3 physical size of GPHS RTG
    - Pel = 10W, Pth = 125W
- Thermal
  - Active: Heat of RTG is used.
  - Heat switch and radiator to avoid overheating during cruise
    - Heat switch to be enhanced.
  - Heat shield: Basotec Foam, Huygens heritage
- Communication
  - UHF link for communication between Hub and Remote Units (max. distance: 25km, Pt = 1W)
  - X-Band for uplink to Orbiter, 2Mbit/s (Redundance via UHF link)
  - No DTE

CPA THERMOELECTRIC GENERATOR
Min-K Insulated Aeroshell
(External Insulation)
Cylindrical Configuration







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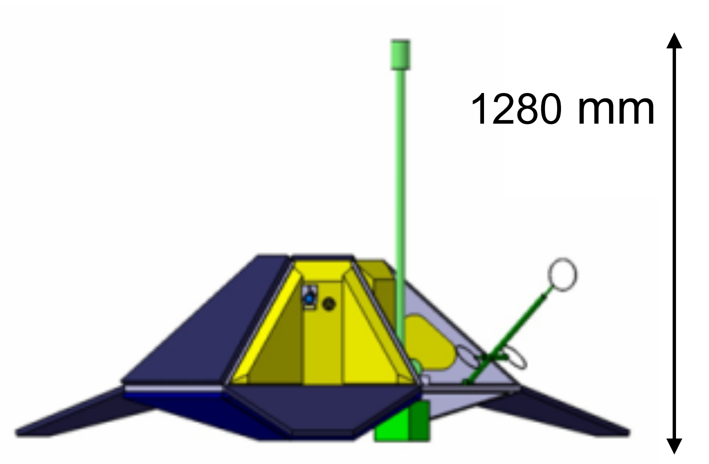
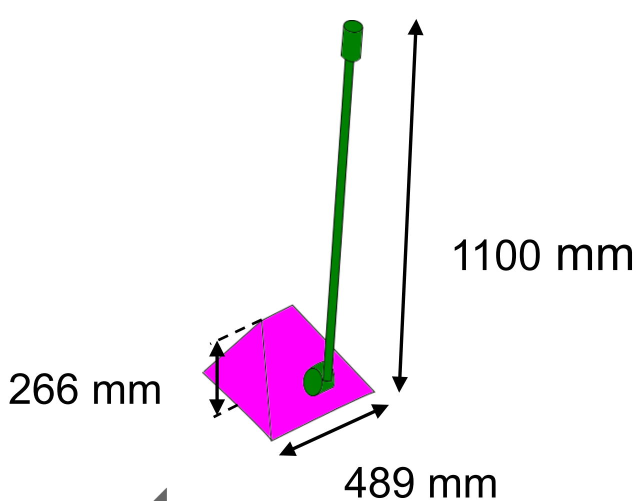
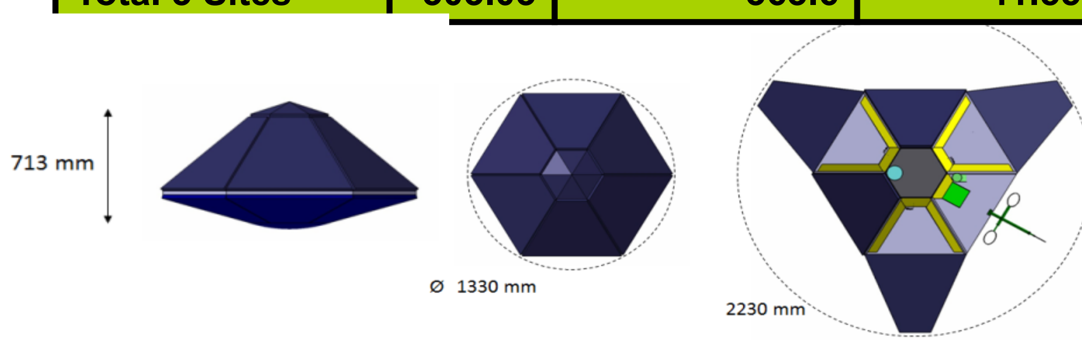
Mass Budget: Total



	Mass [kg]	Mass including margins [kg]	Instrument Mass [kg]
Entry Probe	**10.58**	**12.69**	**1.40**
Hub	**54.85**	**65.82**	**10.75**
Remote Unit	**11.86**	**14.23**	**1.7**
Total per Landing Site	**101.01**	**121.2**	
Total 3 Sites	**303.03**	**363.6**	**41.55**





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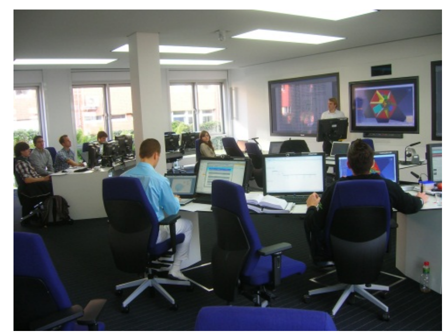
Thank you!

The TiNet Study Team



Backup Slides

Instrument Suites: Hub

Instrument	Quantity	Mass / unit [kg]	Mass Total [kg]
Very Broadband Seismometer (Opt 2)	1	2.30	2.30
Tiltmeter (Geosystems)	1	0.50	0.50
Magnetometer (TU Braunschweig)	1	0.05	0.05
Micro-Seismometer/Acoustic sensor (Active)	3	0.40	1.20
Titan Electric Environment Package – Lander (TEEP-L)	1	0.50	0.50
MetBoom	1	0.50	0.50
Titan Probe Imager, Radiometer	3	0.50	1.50
Surface Science Package	1	4.20	4.20
Total			**10.75**

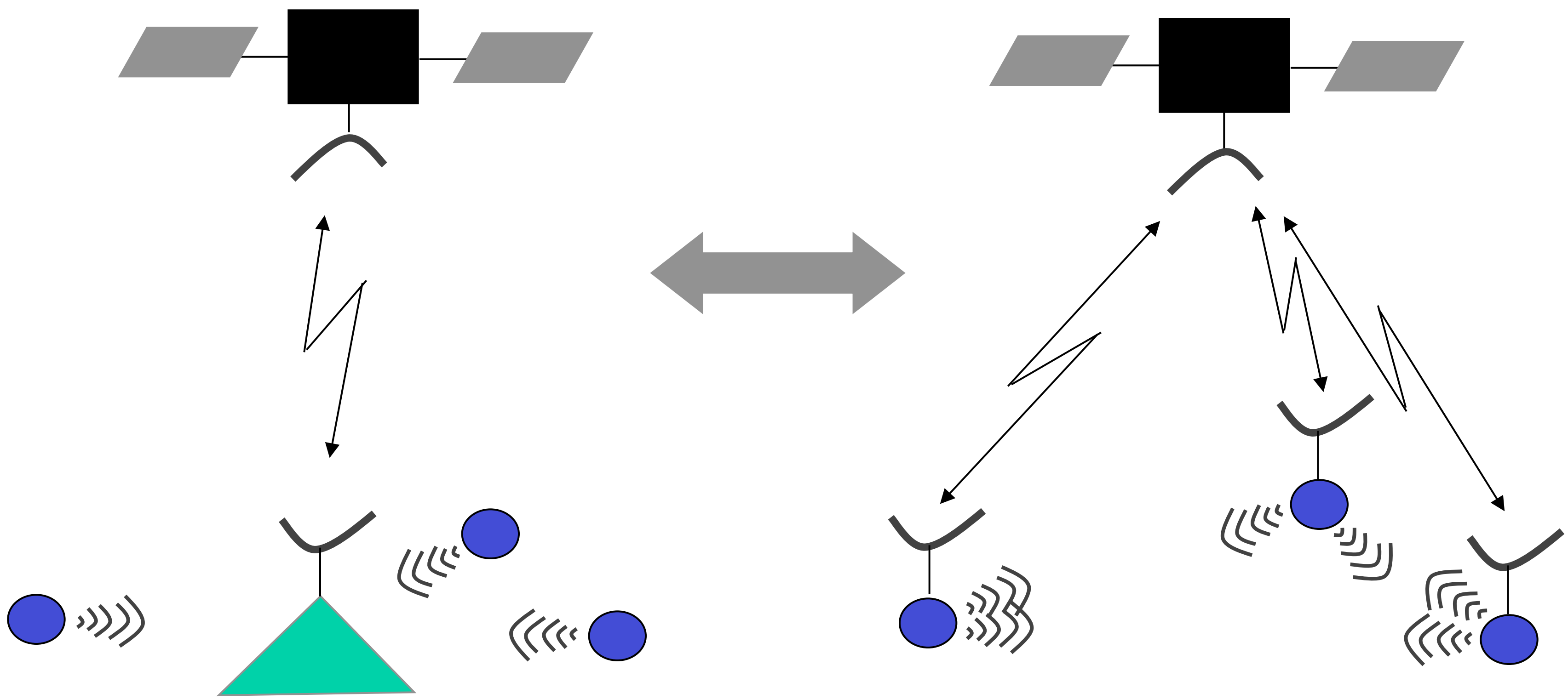
- **On Hub, but for science during descent:**
  - **1 kg descoped HASI**
  - **0.4 kg descent camera**

Instrument Suites: Remote Unit

Instrument	Quantity	Mass / unit [kg]	Mass Total [kg]
Micro-Seismometer/Acoustic sensor	1	0.40	0.40
Magnetometer (3-axial)	3	0.10	0.30
Micro-GCMS (Massenspectrometer / MEMS)	1	0.50	0.50
MetBoom	1	0.50	0.50
Total	**6**		**1.70**

System Trade 1: Network Architecture

-Centralized Architecture -vs. -Decentralized Architecture



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Centralized vs Decentralized

- Hub/Remote: Central Station (Hub) + 3 simple instrument packages (Remote Units)
- Local Network: 3 more „advanced“ instrument packages

	Pro	Con
Hub/Remote	• No intelligence on subunits required • Subunits can be more simple/only instrument „survival“ required • Reduced mass on remote units (Comm, Data Handling) • Instrument disturbancies/interferences from subsystems are reduced • Interfaces and configuration (to instruments) easier to be standardized • Option to implement active seismology	• 2 dedicated designs (Remote Unit and Hub)
Local Network	• No single-point failure (redundancy) • Only one single design • Single unit has higher applicability for future missions • Descent scenario simplified • Simpler/more reliable communication scheme	• Reduced P/L to system mass ratio

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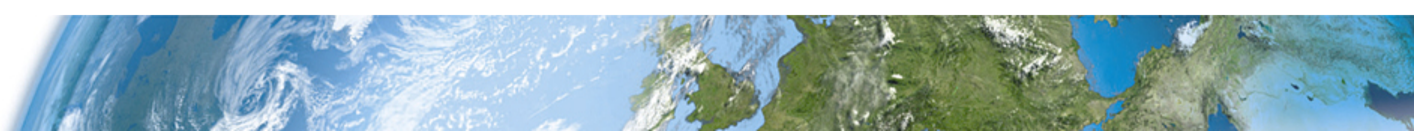
Selected Network Architecture

	P/L mass	Ease of Deployment	Reconfig.	Reliability /Risk	Data Rate / Comm	Lifetime
Hub/Remote	+	-	+	-	+	o
Local Network	-	+	-	+	-	o

- Hub/Remote configuration is the chosen architecture
- Lake vs. Soil: different equipment (e.g. some instruments exchanged, eventually modified mechanisms), same configuration



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Trade 2: Deployment Scenario cont‘d

- Option 1: Hub is carrier for remote units during entry → early separation (height 60km) and descent of RU‘s separately
- Option 2: deployment after landing
- Requirements: from science 1-10 km separation; from communication max. 10 km

	Unit mass	Landing Disperion	Landing stability	Reliability / Risk	Science Return
RU deployment during descent	-	+	+	-	+
RU deployment after landing	+	-	-	+	-

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