

Cloud Height Mission

Klemen Zakšek¹, Marcello Valdatta²

K. Oštir³, M. Hort¹, A. Marsetič³,
N. Bellini², D. Rastelli², A. Locarini², S. Naldi²

¹ University of Hamburg, Germany

² Npc Spacemind, Italy

³ Center of Excellence SPACE-SI, Slovenia

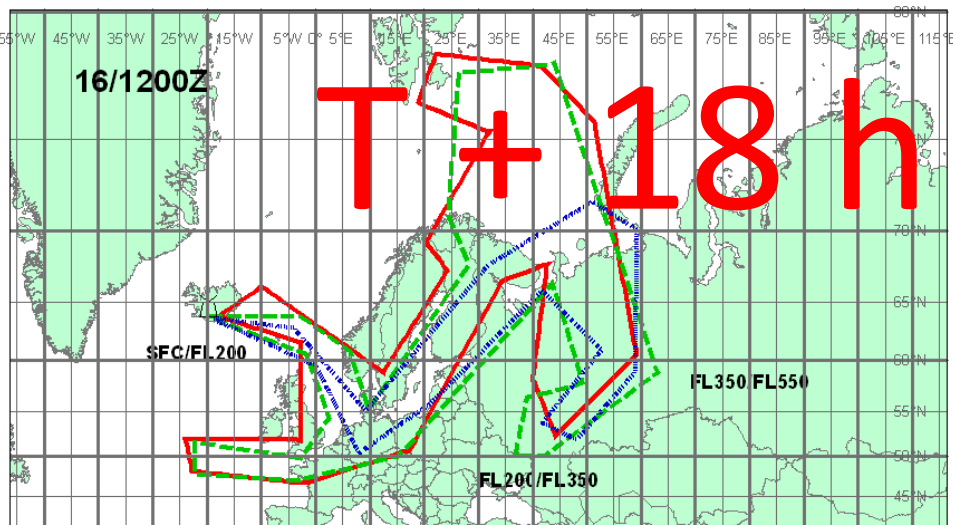
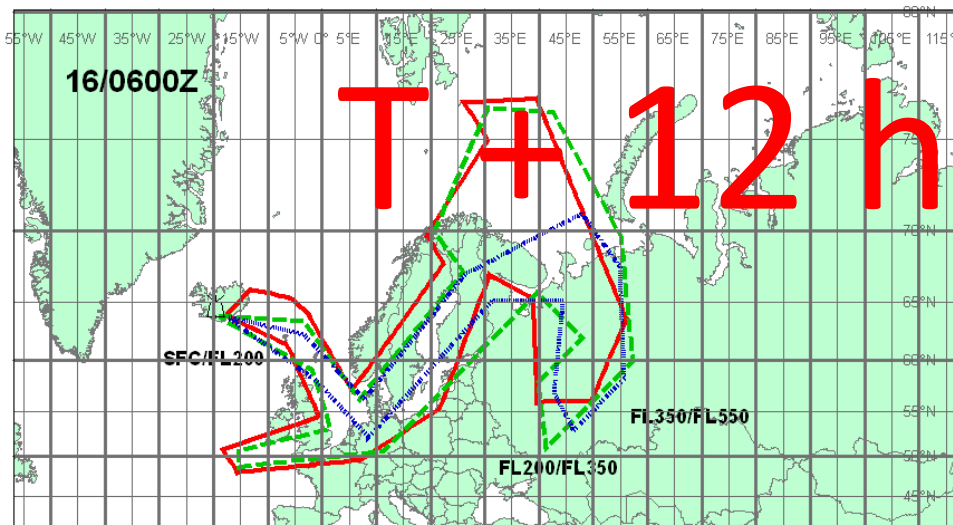
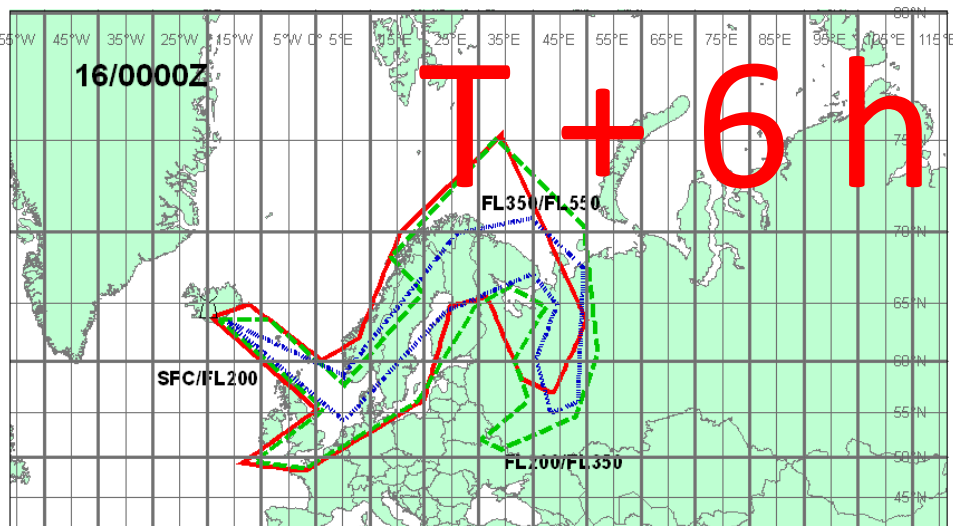
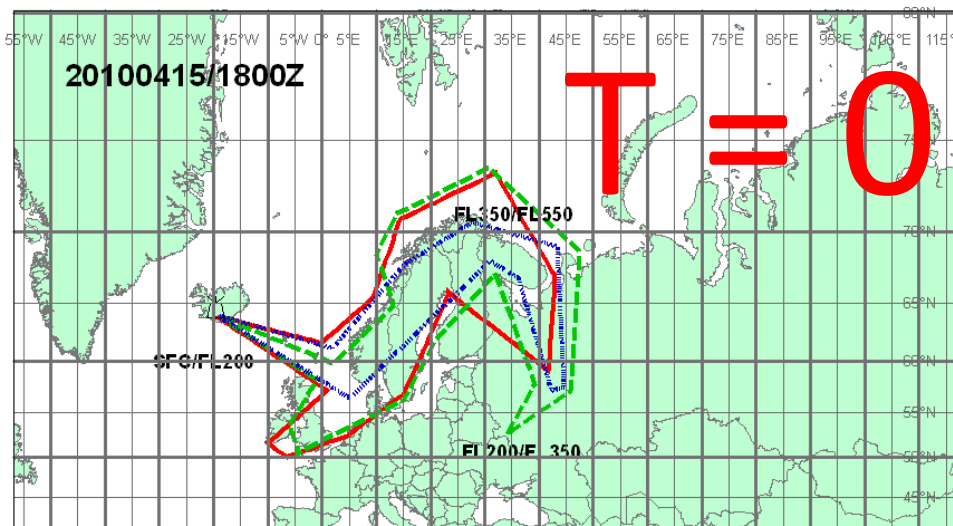
1989 Redoubt: **KLM flight 867**



- ATC: Do you have good sight of the ash plume?
- Pilot: It's just cloudy. It could be ash. It's just a little browner than a normal cloud.
- Pilot: We have to go left now... It's smoky in the cockpit at the moment sir.
- ATC: KLM 867 heavy, rodder, left at your discretion.
- Pilot: Climbing to (flight) level 390, we're in the black cloud, heading 130.
- Pilot: KLM 867 we have **FLAME OUT ALL ENGINES** and we are descending now.
- ATC: KLM 867 heavy... Anchorage.
- Pilot: KLM 867 heavy, we are descending now... **WE ARE IN A FALL!**

Past encounters with volcanic ash

- 1953–2009: 129 encounters
- Severely damaging: 26
- Engine failure: 9
 - Last in 2006
 - Distance from volcano: 100–930 km
 - Encounter duration: 2–13 min



VA ADVISORY
 DTG: 20100415/1800Z
 VAAC: LONDON
 VOLCANO:
 EYJAFJALLAJOKULL
 PSN: N6338 W01937
 AREA: ICELAND

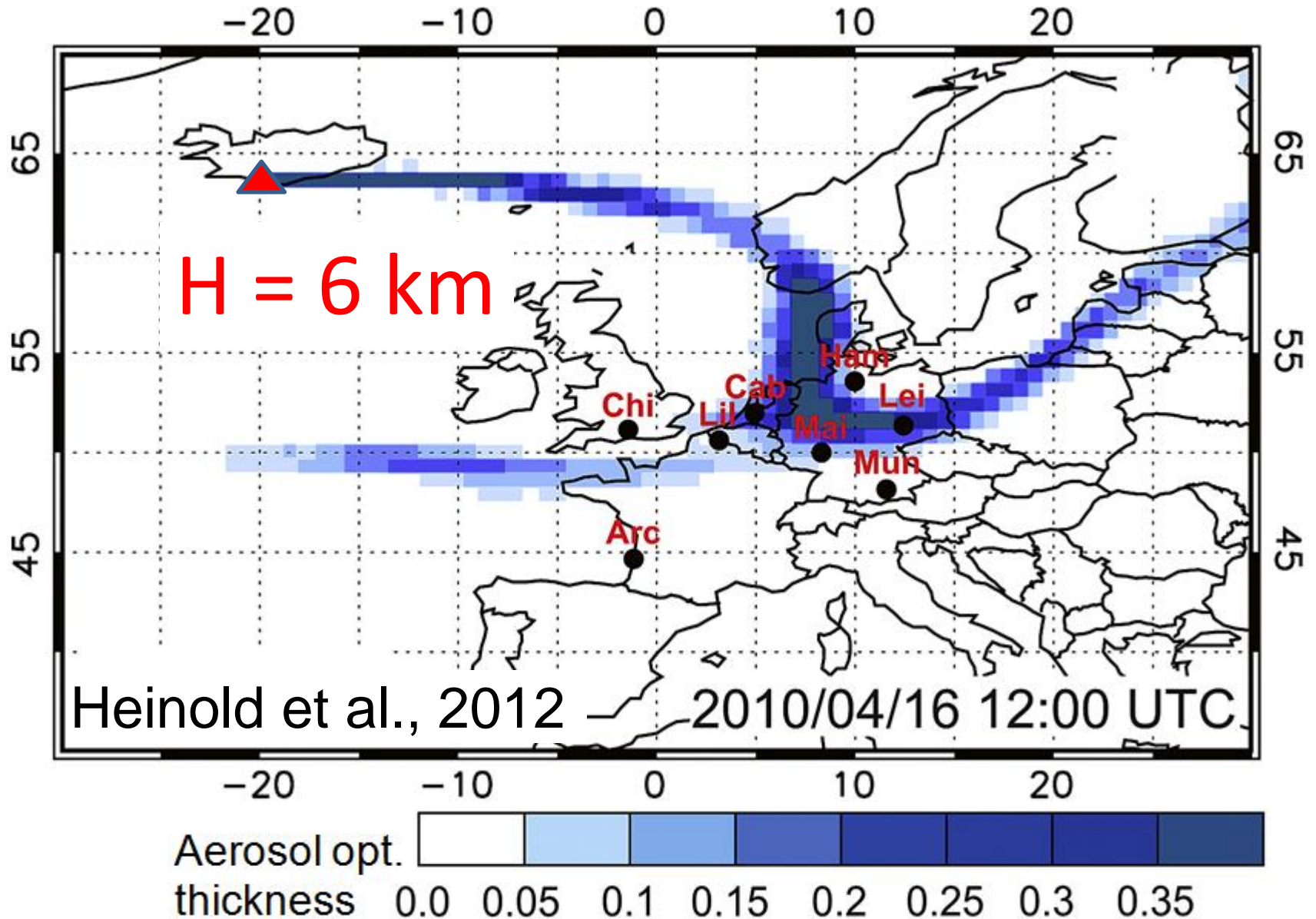
SUMMIT ELEV: 1666M
 ADVISORY NR: 2010/007
 INFO SOURCE: ICELAND MET OFFICE
 AVIATION COLOUR CODE: RED
 ERUPTION DETAILS: SIGNIFICANT ERUPTION
 CONTINUING. PLUME REACHING FL150, BUT
 POSSIBLY OCCASIONALLY TO FL330

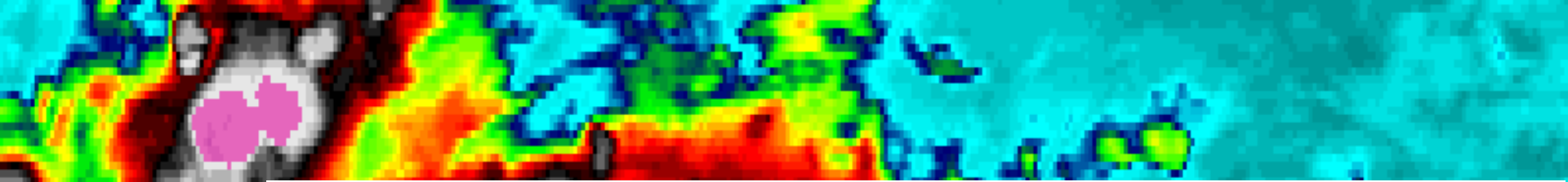
RMK: ASH CONCENTRATIONS WITHIN THE INDICATED AREAS ARE
 UNKNOWN
 NXT ADVISORY: 20100416/0000Z



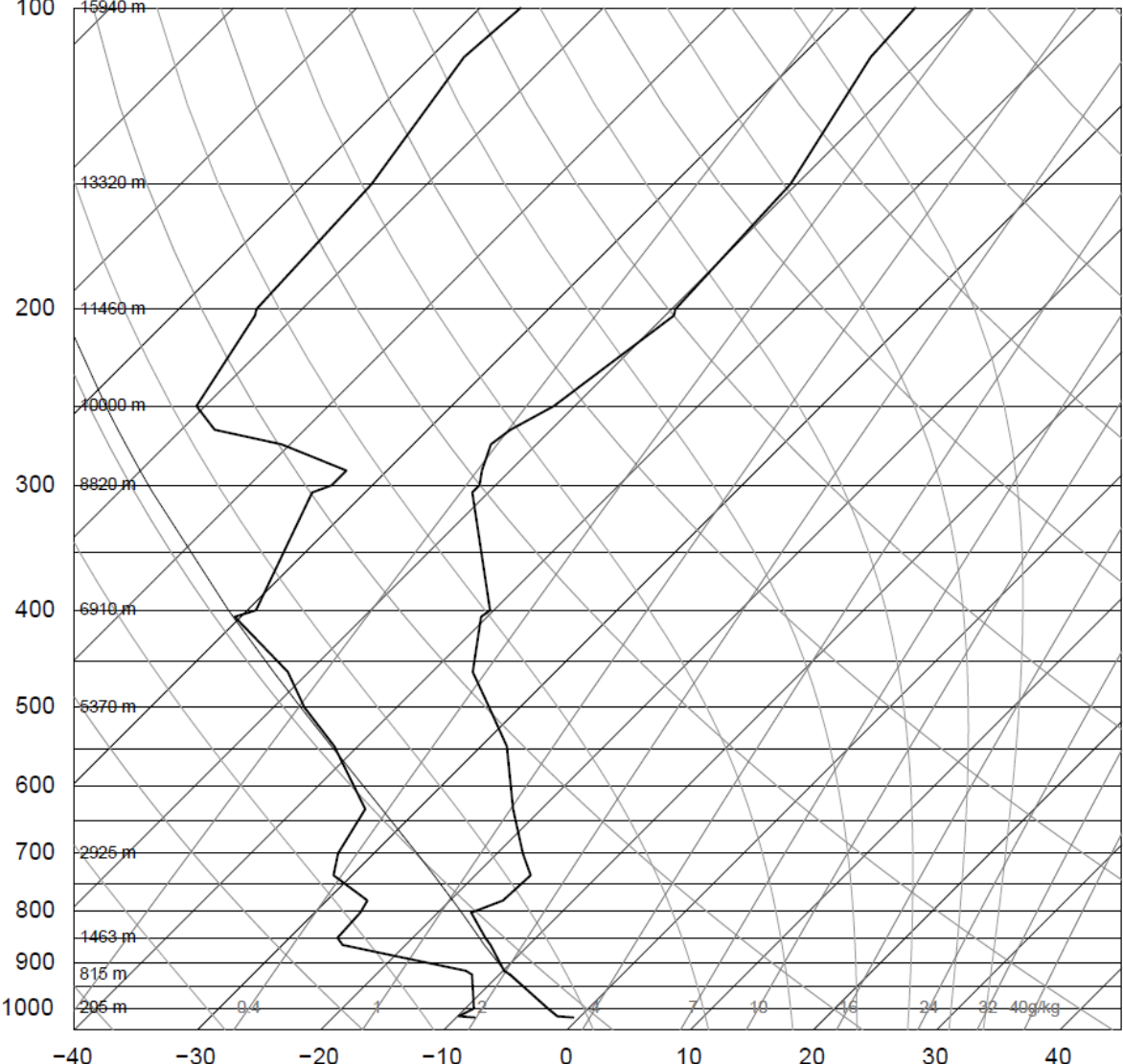
1.3 billion EUR in 6 days

Model of 2010 Eyjafjallajökull eruption

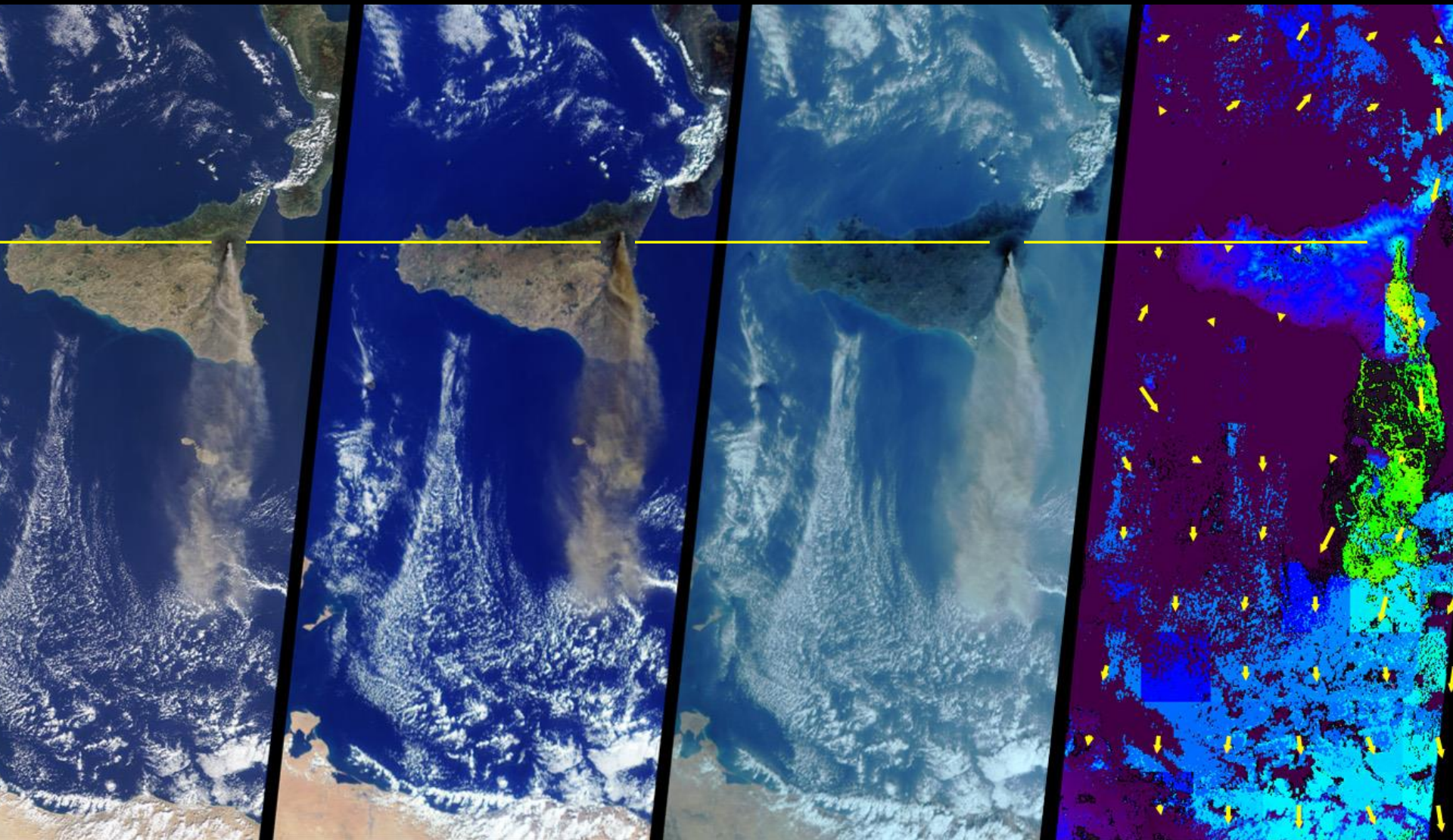




04018 BIKF Keflavikurflugvollur



SLAT	63.96
SLON	-22.60
SELV	54.00
SHOW	16.93
LIFT	15.29
LFTV	15.30
SWET	98.00
KINX	-22.7
CTOT	6.40
VTOT	18.40
TOTL	24.80
CAPE	0.00
CAPV	0.00
CINS	0.00
CINV	0.00
EQLV	-9999
EQTV	-9999
LFCT	-9999
LFCV	-9999
BRCH	0.00
BRCV	0.00
LCLT	262.0
LCLP	901.7
MLTH	269.9
MLMR	1.83
THCK	5165.
PWAT	3.88



nadir

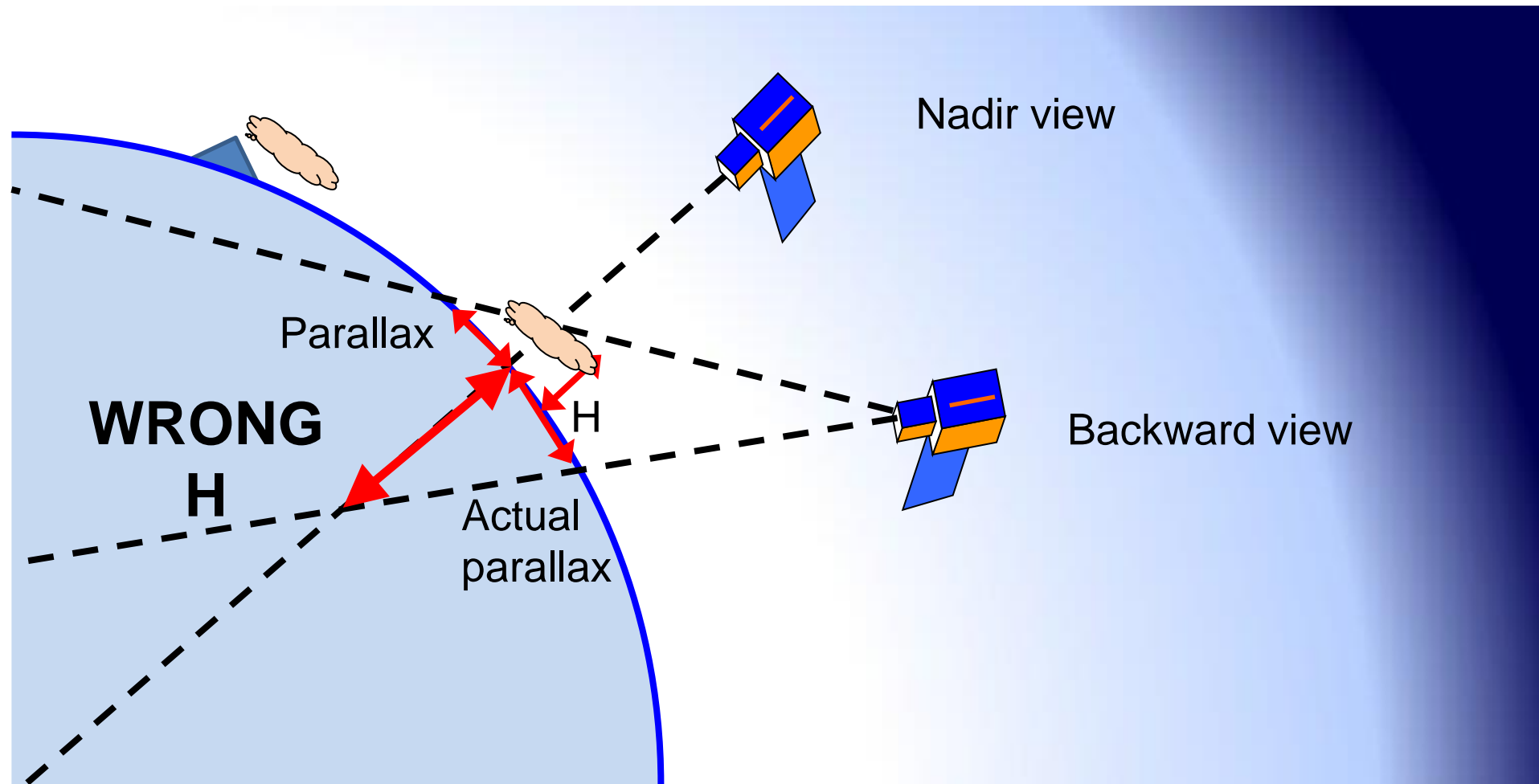
70° backward

70° forward

0 2 4 6 8 10
height in kilometers

2002 ETNA Eruption; courtesy NASA JPL, MISR Team

Photogrammetry from a **single** satellite



Simultaneous observations
from **2** micro satellites



Mission **objectives**

Aviation safety and cost reduction!

- 200 m vertical accuracy
- 150 m relative horizontal accuracy
- revisit 1+ per day
- 5+ retrievals in 1 min (on demand)

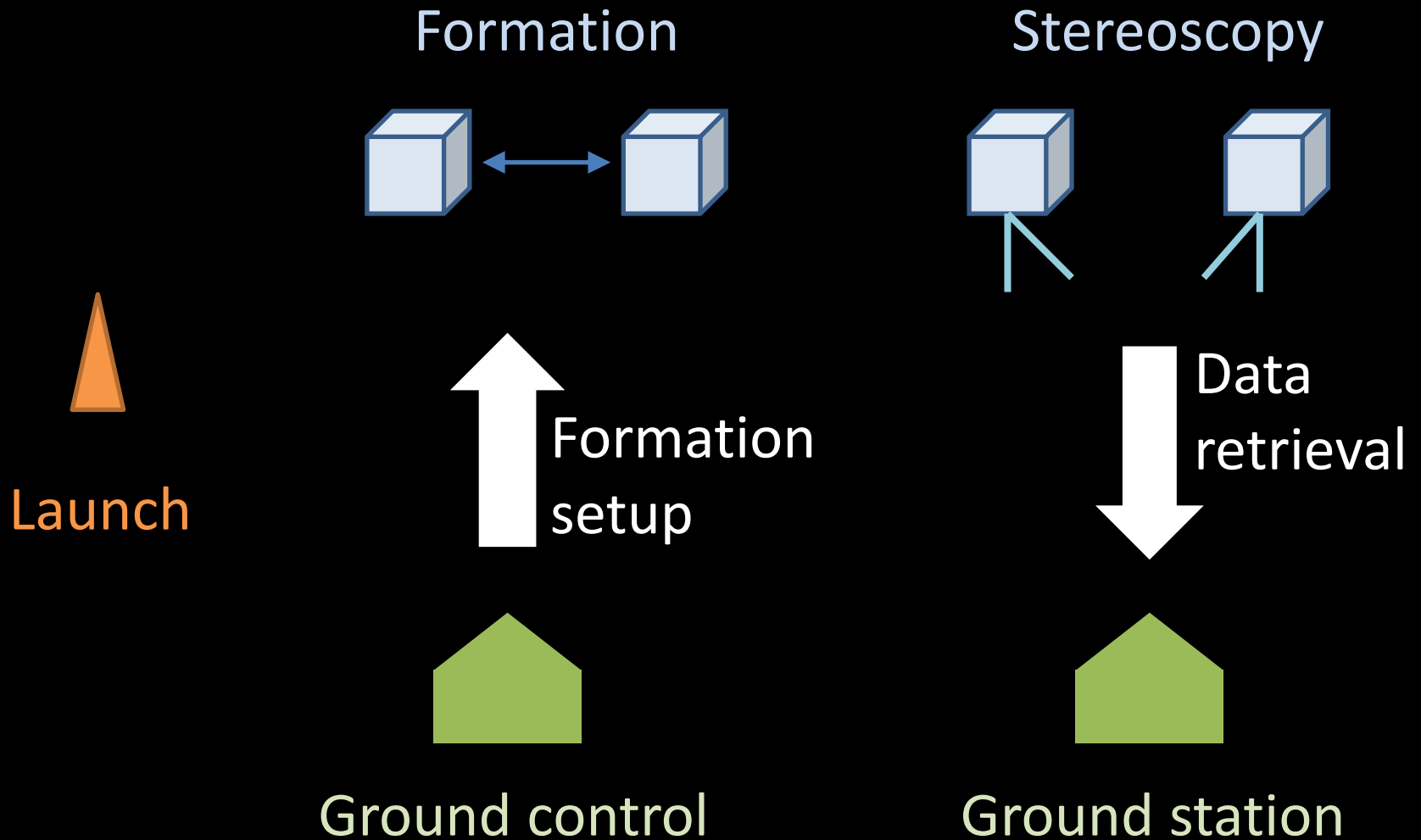
Observe **meteorological** and other **aerosol** clouds!



Performance parameters

- 2+ satellites in formation; $H = 600$ km, $D = 400$ km
- Simultaneous retrieval
- Pointing to the same point
- resolution_{VIS} = 300 m
- resolution_{TIR} = 1500 m

Operations concept



Satellite 1
„Bonnie“

VIS
camera

TIR
camera

Satellite 2
„Cloud“

VIS
camera

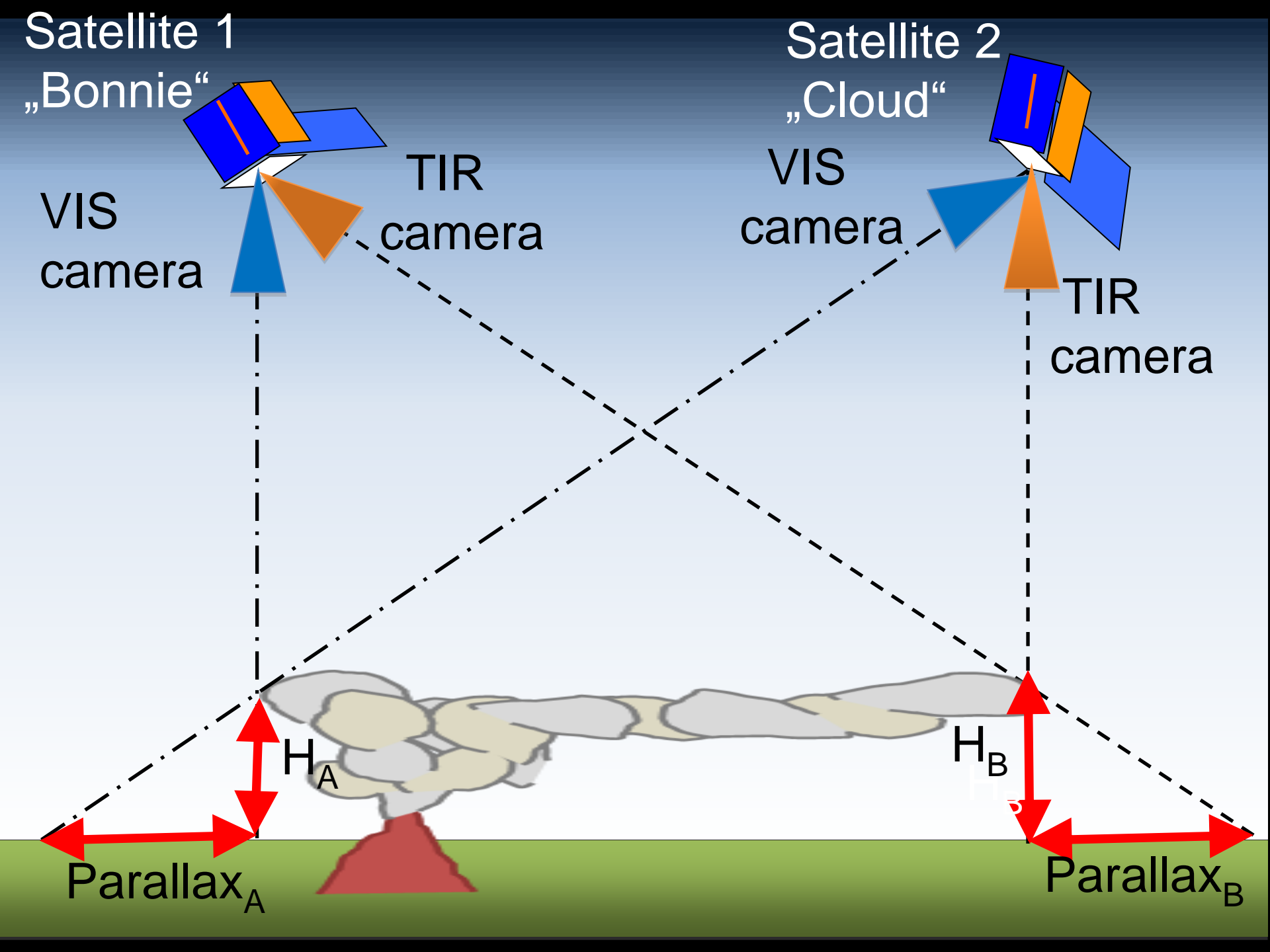
TIR
camera

H_A

H_B

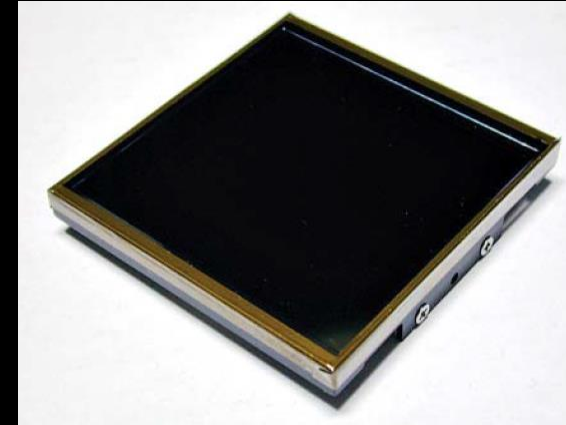
Parallax_A

Parallax_B



Payload

- **VIS** sensor
 - Fairchild Imaging CCD486
 - 30 mm lense
 - resolution_{VIS} = 300 m
 - Swath = 1200 km
- **TIR** sensor
 - Teledyne Dalsa / FLIR / Infratec
 - resolution_{TIR} = 1500 m
- **GNSS** receiver



General specifications

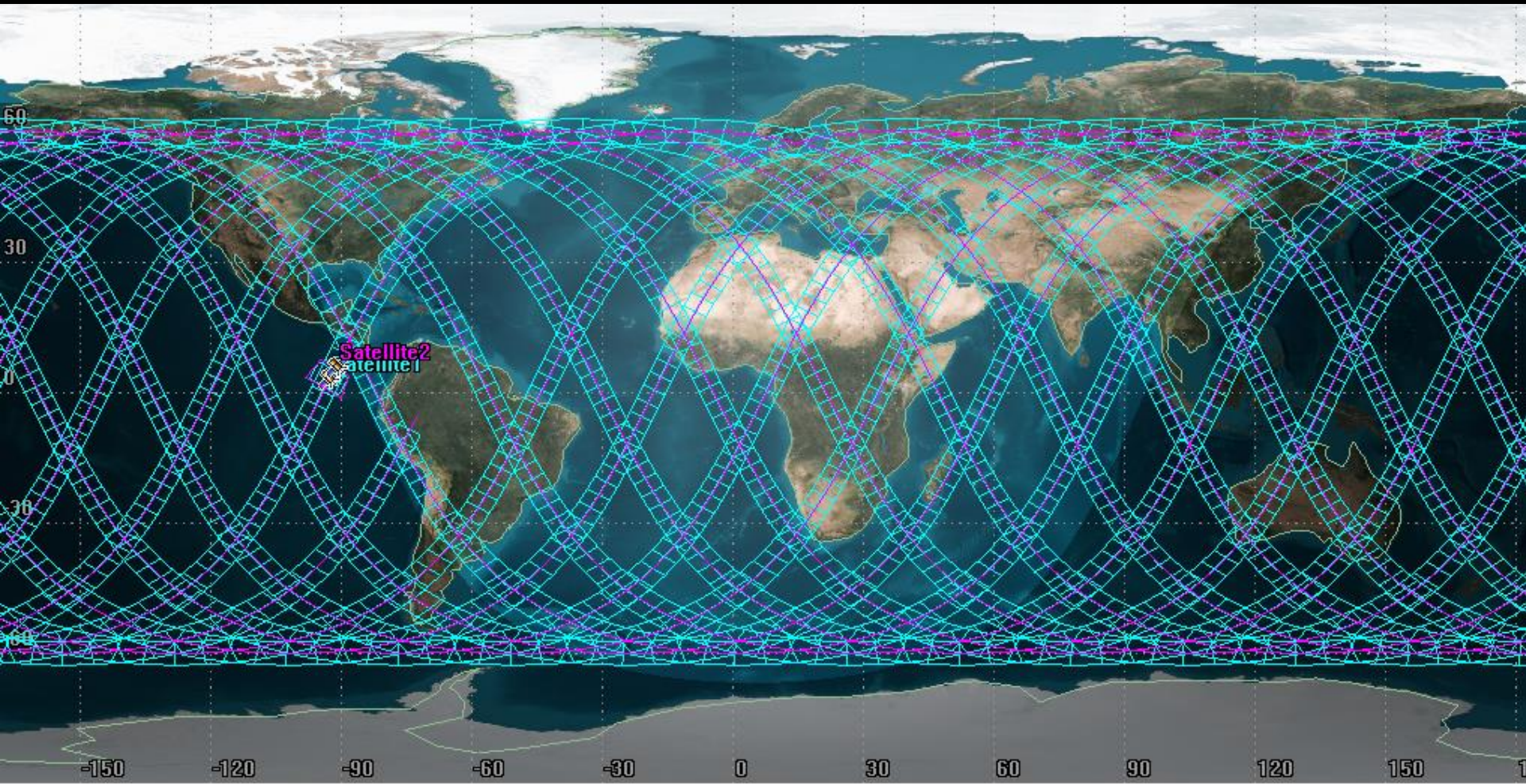
- Total mass < 30 kg
- Dimensions 300×300×300 mm
- ADCS
- Propulsion to start the flight formations
- Deorbiting device (Sail or D-Orbit system)
- Power consumption 22 W (peak)
- Costs ~ 0.5 Million EUR

Link budget

- 6 ground stations
- 300 MB per orbit

Parameter:	Value:	Units:
Spacecraft:		
Spacecraft Transmitter Power Output:	20,0	watts
In dBW:	13,0	dBW
In dBm:	43,0	dBm
Spacecraft Total Transmission Line Losses:	2,2	dB
Spacecraft Antenna Gain:	5,0	dBi
Spacecraft EIRP:	15,8	dBW
Downlink Path:		
Spacecraft Antenna Pointing Loss:	0,0	dB
S/C-to-Ground Antenna Polarization Loss:	0,2	dB
Path Loss:	167,4	dB
Atmospheric Loss:	2,1	dB
Ionospheric Loss:	0,1	dB
Rain Loss:	0,0	dB
Isotropic Signal Level at Ground Station:	-154,0	dBW
Ground Station (Eb/No Method):		
----- Eb/No Method -----		
Ground Station Antenna Pointing Loss:	6,2	dB
Ground Station Antenna Gain:	31,8	dBi
Ground Station Total Transmission Line Losses:	2,0	dB
Ground Station Effective Noise Temperature:	510	K
Ground Station Figure of Merit (G/T):	2,8	dB/K
G.S. Signal-to-Noise Power Density (S/No):	71,2	dBHz
System Desired Data Rate:	1000000	bps
In dBHz:	60,0	dBHz
Telemetry System Eb/No for the Downlink:	11,2	dB
Demodulation Method Selected:	BPSK	
Forward Error Correction Coding Used:	Convolutional R=1/2, K=7	
System Allowed or Specified Bit-Error-Rate:	1,0E-06	
Demodulator Implementation Loss:	0	dB
Telemetry System Required Eb/No:	4,8	dB
Eb/No Threshold:	4,8	dB
System Link Margin:	6,4	dB

Inclined orbit



• Active volcanoes in last 10,000 years

Denisty of airline routes

Risks

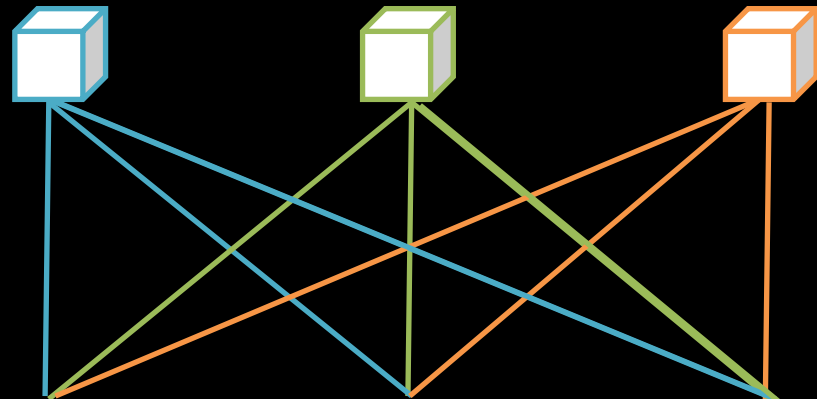
Ground station without access

Sensors failure

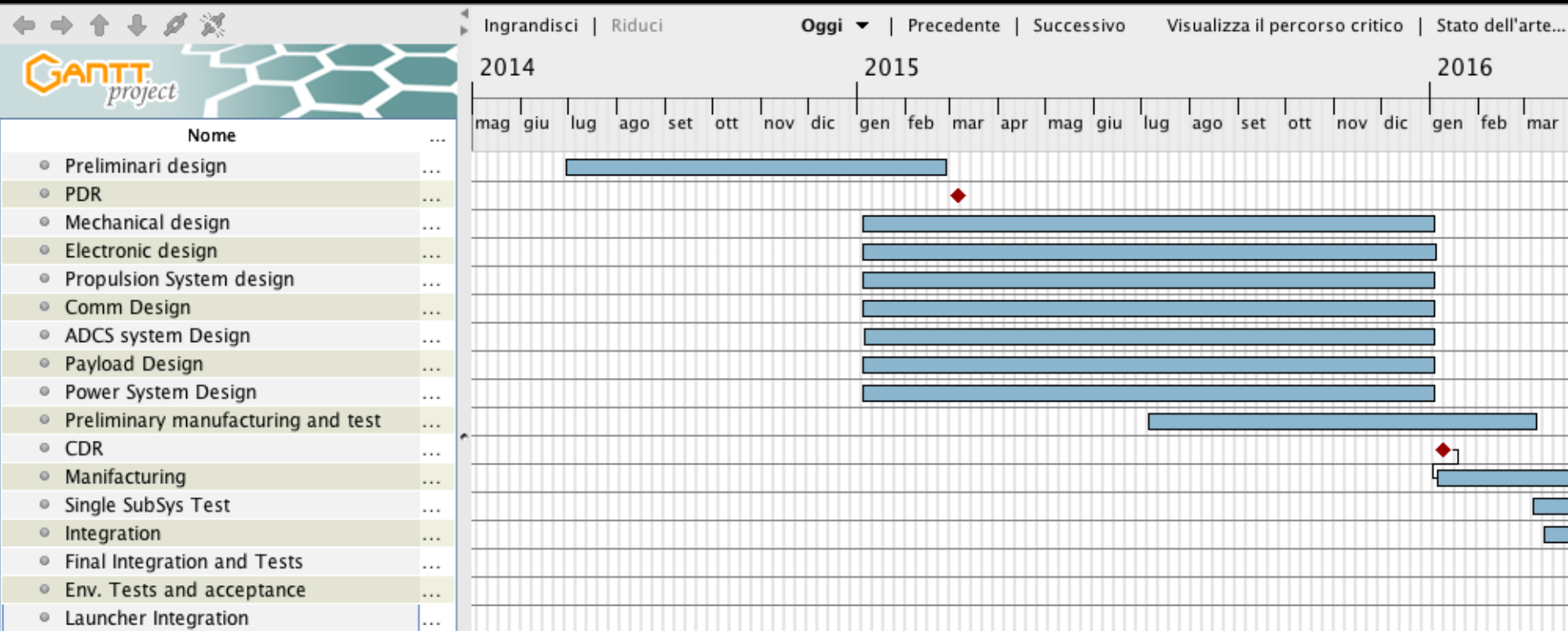
Launch System failure →
Loss of both satellite

Pointing manoeuvre failure

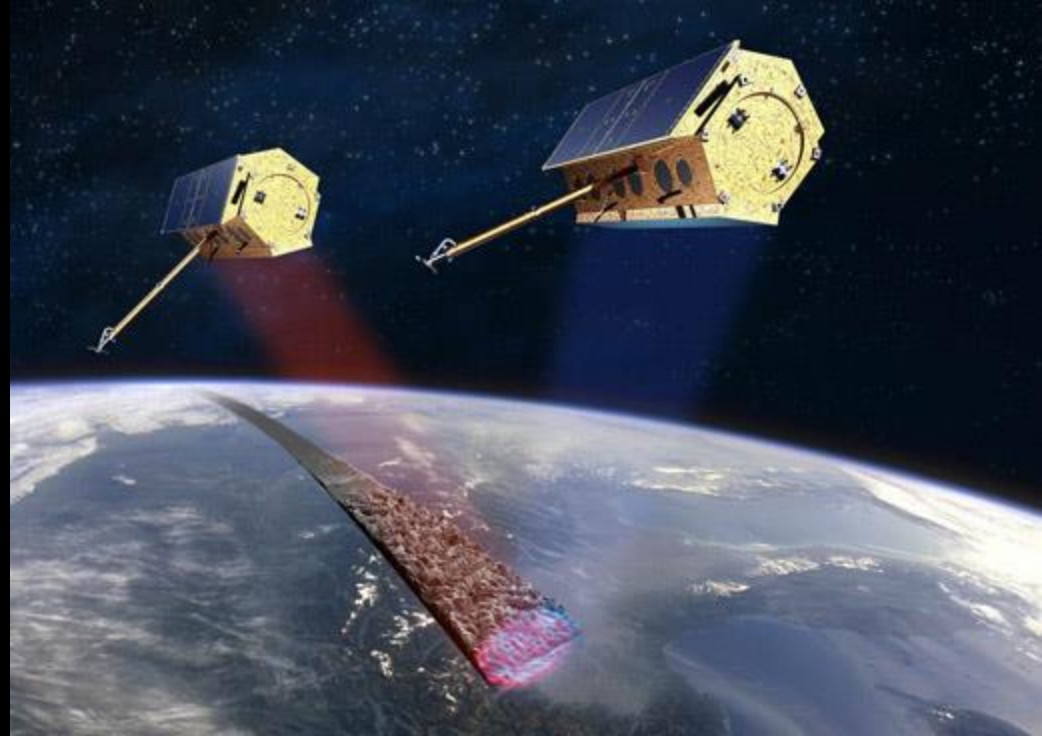
One of satellite fails in orbit



Concept



klemen.zaksek@zmaw.de



Zakšek, K., et al.:

Monitoring volcanic ash cloud top height through simultaneous retrieval of optical data from polar orbiting and geostationary satellites

Atmos. Chem. Phys., 13, 2589-2606,

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