Dual Retrievel Of Precipitation

Blue Team

represented by Alex Jarosch and Sebastian Trowitzsch

Summer School Alpbach - 5th Aug. 2010

Mission Summary

"The DROP mission goal is to provide precipitation measurements in mid to high latitudes with a focus on snow and rain detection."

- Improve climate model predictions by contributing to **process understanding**
- Improve global precipitation estimates in sparsely covered regions
- Improve global datasets of cloud parameters (hydrometeor types, fall-out speed, particle size distributions. . .)

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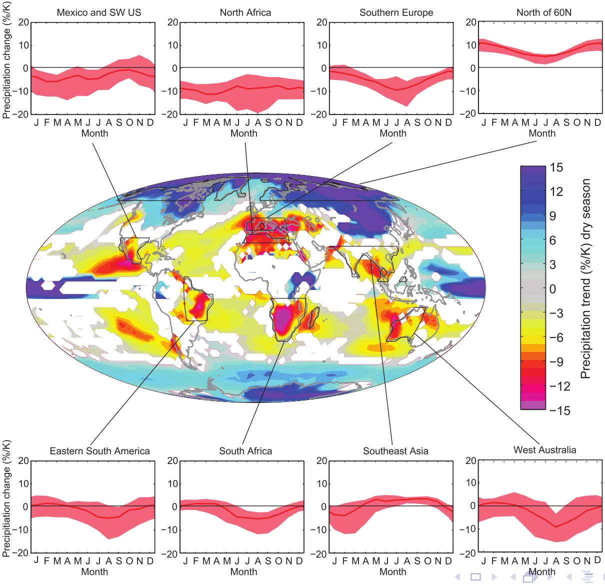
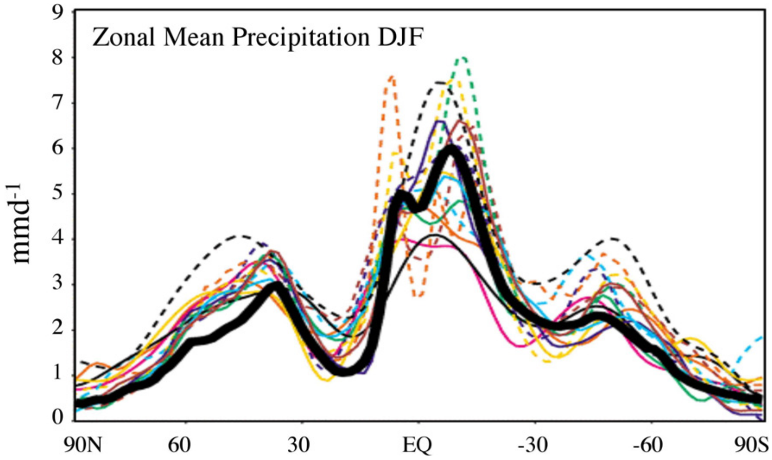
Scientific Justification - predicted precipitation change [%/K]



Scientific Justification - GCM differences



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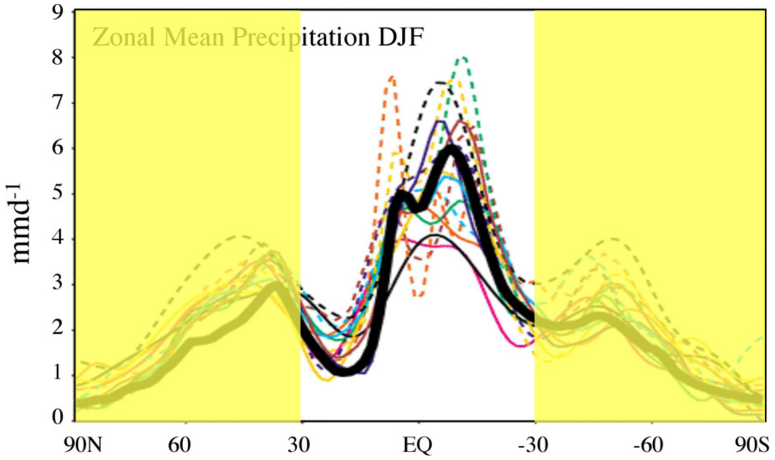

Scientific Justification - Why ? GCM differences

- Complex cloud physics and precipitation processes
- physics not available or impossible to implement
- -> parameterizations needed
- -> need evaluation

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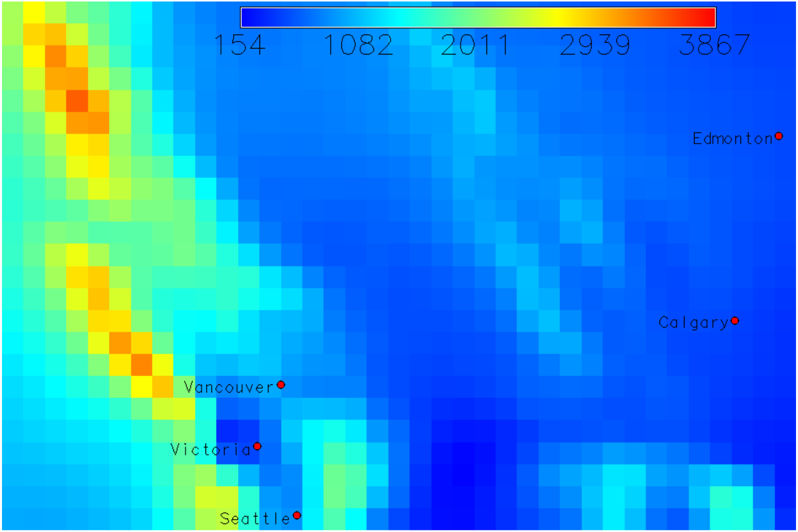
Scientific Justification - Model Evaluation



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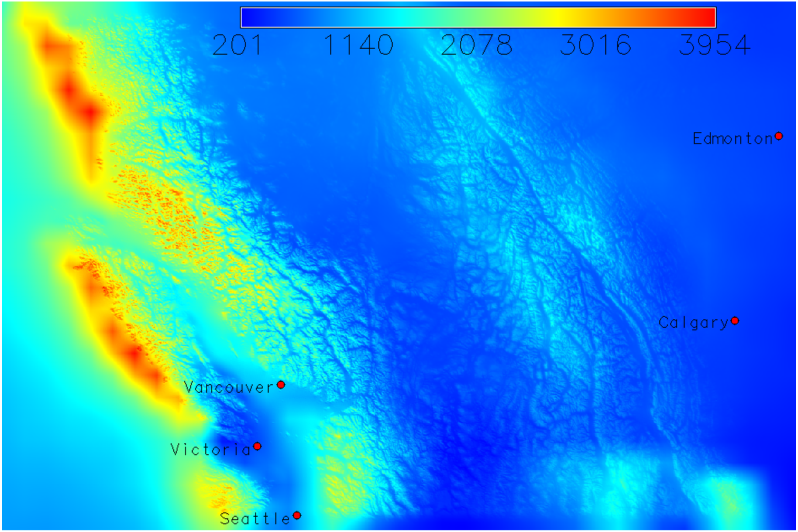

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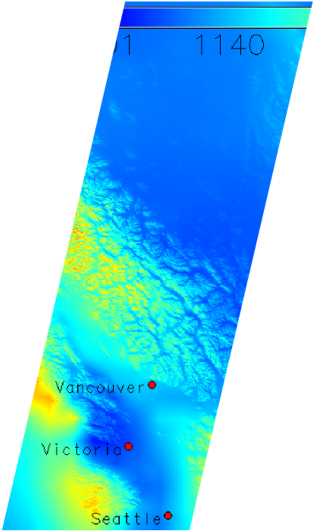
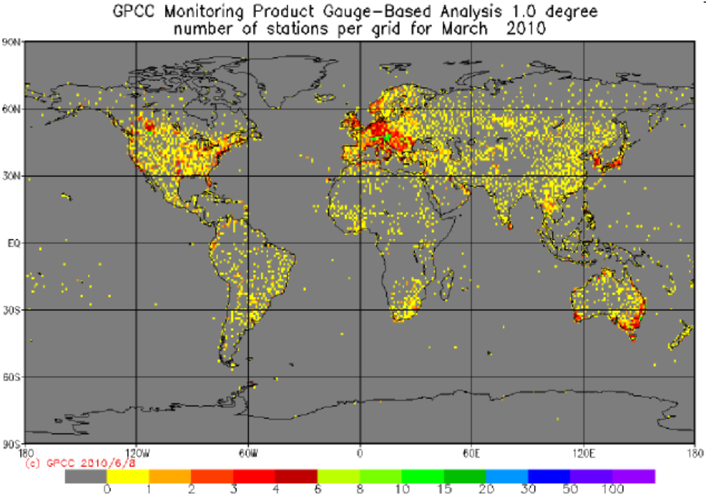
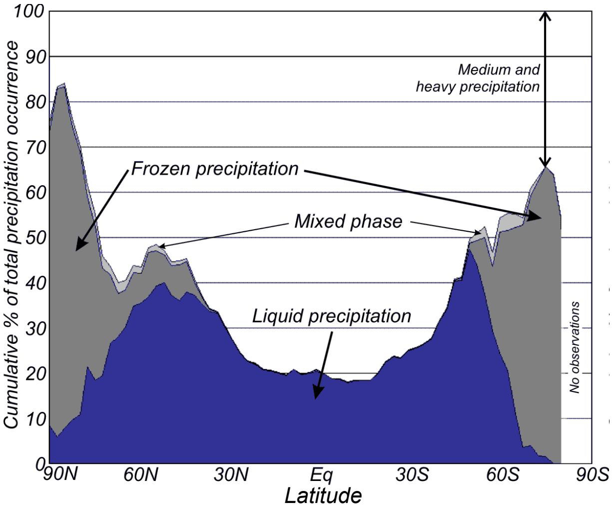


Scientific Justification - Why from space?



Scientific Justification - Why rain and snow?



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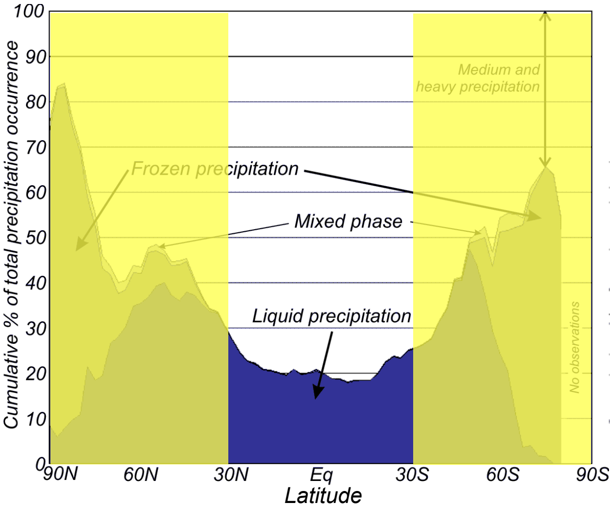

Scientific Requirements

- Precipitation Rates at higher Latitudes ($> 30°$)
- Quantification of Precipitation
  - Resolution 250 m Vertical / 2 km Horizontal
  - Dynamic Range 0.1 - 20 mm/h
  - Dynamic Range Doppler 0 - 10 m/s
- Revisit Time: 1-4 days
- Life Span: 5 years
- Instruments
  - Passive Microwave (1389 km swath)
  - Active Radar (417 km swath)

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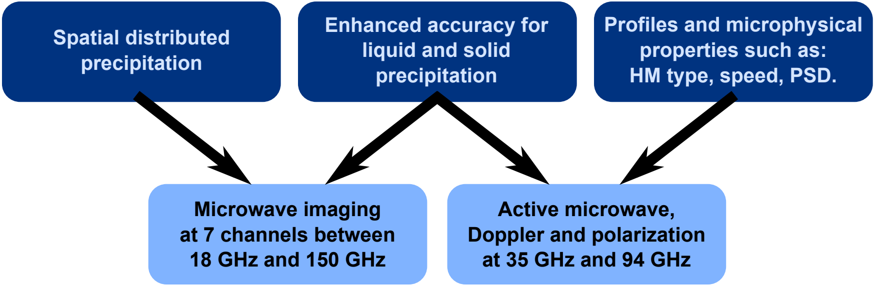
Observation Technique

Spatial distributed precipitation

Enhanced accuracy for liquid and solid precipitation

Profiles and microphysical properties such as: HM type, speed, PSD.

Observation Technique



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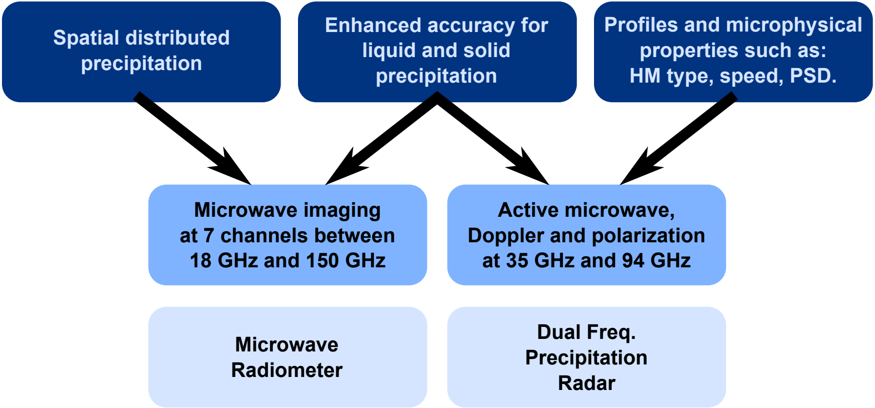

Active Radar Principle

$$P_r = \text{const.}\frac{P_t G^2 \lambda^2}{(4\pi)^3 R^2} L_a^2 \sigma_v \frac{c\tau}{2} \quad (1)$$

$$\sigma_v = \frac{\pi^5}{\lambda^4} |K_r|^2 \int_{D_{\min}}^{D_{\max}} D^6 N(D) dD \quad (2)$$

$$Z = \int_{D_{\min}}^{D_{\max}} D^6 N(D) dD \quad (3)$$

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L_a . . . attenuation
τ . . . impulse duration
σ_v . . . volume backscatter coefficient
G . . . antenna gain
K_r . . . dielectric factor
ε_r . . . permittivity

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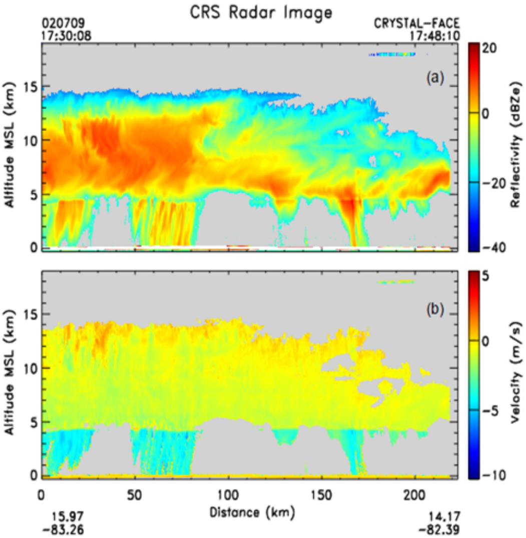

(1)

(2)

(3)

(4)

Active Radar 35 and 94 GHz

- Z - S Relation $Z = A * S^B$
- Improvement of PSD by dual wavelength
- Futher Improvement of PSD by Doppler spectrum
- Dual polarization
  - Differential Z: ZDR = Z(H) / Z(V)
  - Corr. Coeff. (CC) of H to V
    - low CC -> non meteor. targets
    - high CC high Z -> liquid
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    - low CC high Z -> mixed

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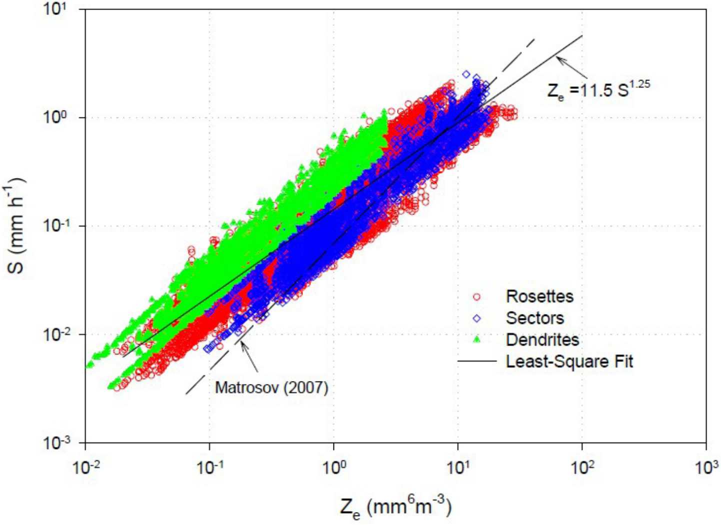

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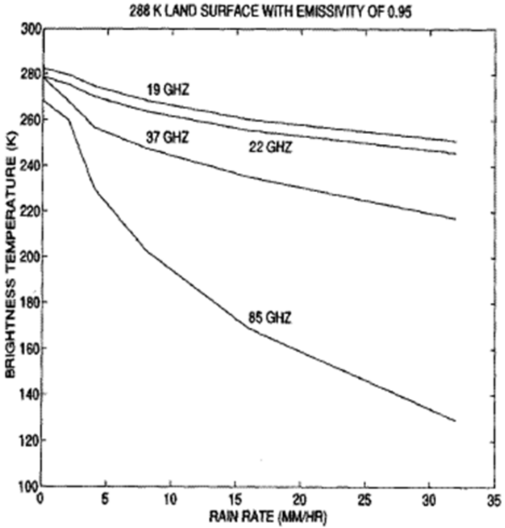
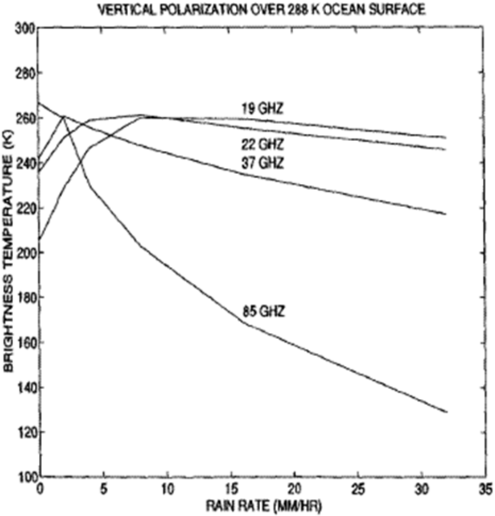
Passive Microwave Radiometer

Land



Passive Microwave Radiometer

Ocean



Measurement requirements

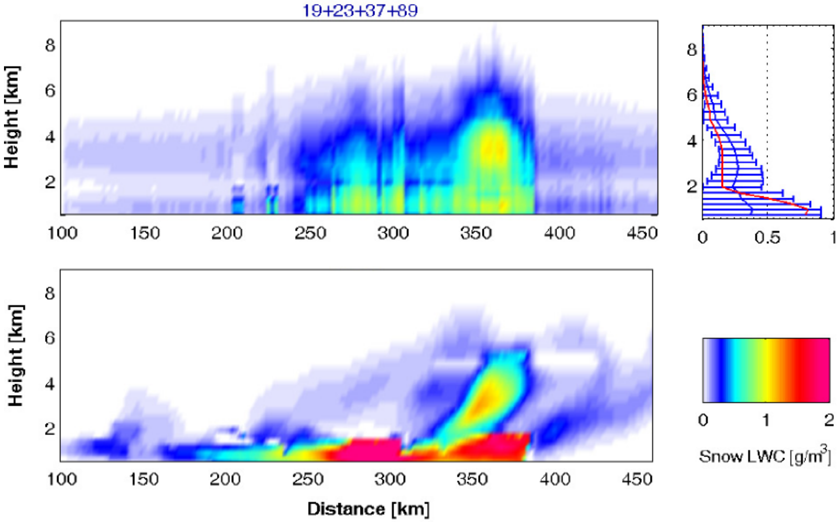
Passive Microwave Radiometer

Channel	18.7 GHz	23.8 GHz	36.5 GHz	54 GHz	89 GHz	118 GHz	150 GHz
Polarisation	H+V	V	H+V	H/V	H+V	H/V	H+V
Sensitivity	< 0.5 K	< 0.6 K	< 0.7 K	< 0.5 K	< 1.0 K	< 1.0 K	< 1.0 K
A. accuracy	< 1.0 K	< 1.0 K	< 1.0 K	< 1.0 K	< 1.0 K	< 1.0 K	< 1.0 K

Active Radar

Parameter	Minimum	Maximum
Precipitation Rate	0.1 mm	20 mm
True Reflectivity	0 dBZ	45 dBZ

Synergy for data



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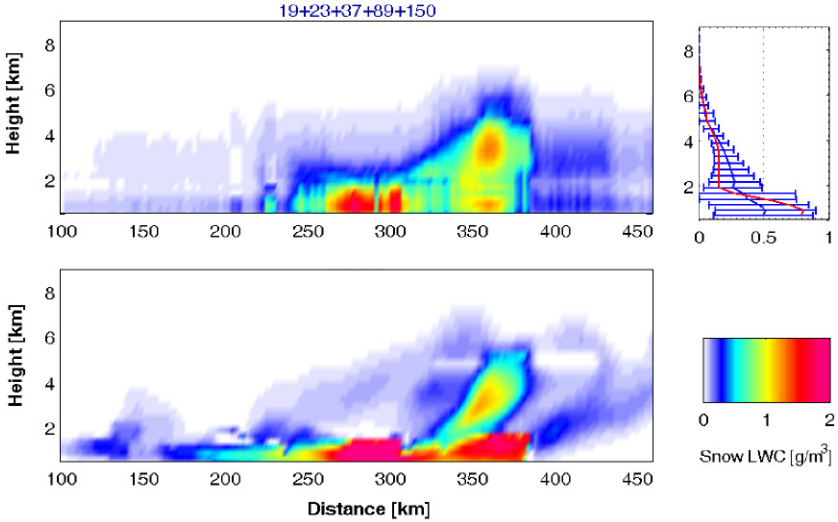

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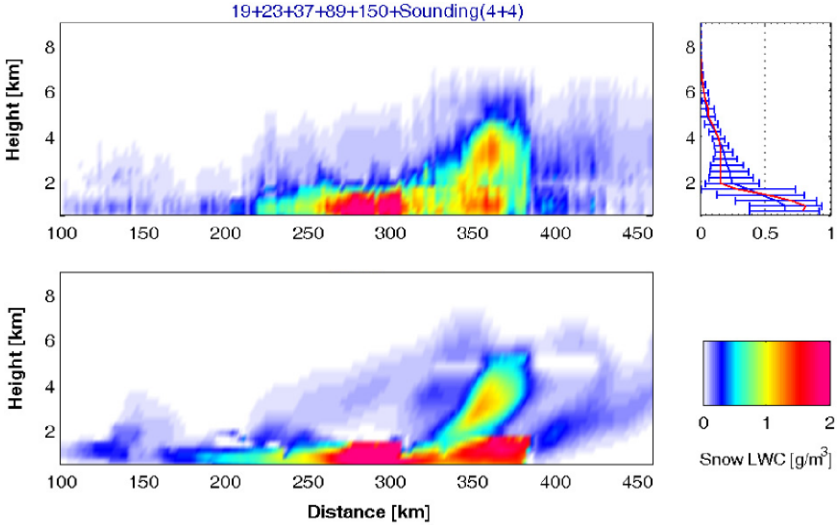

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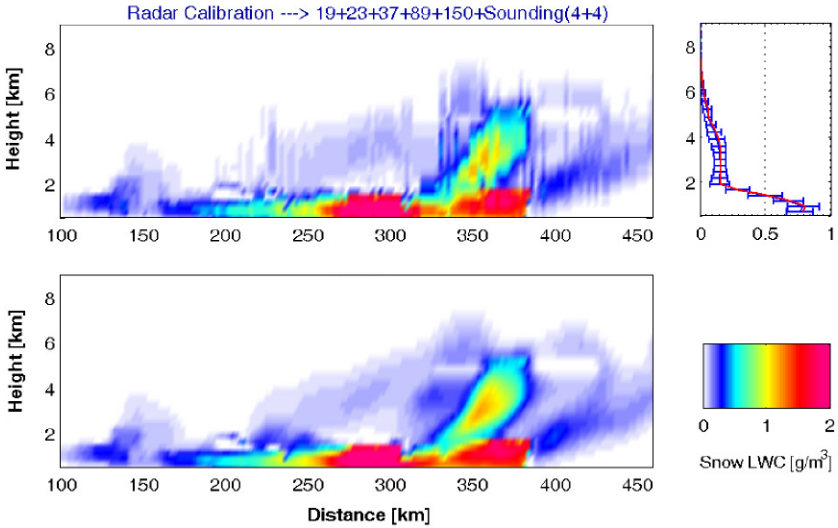
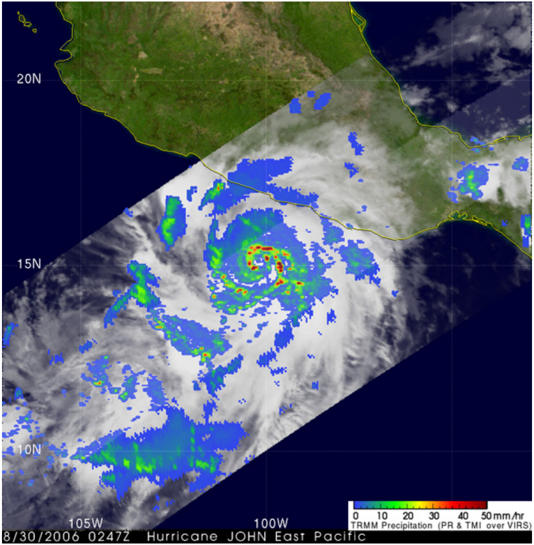
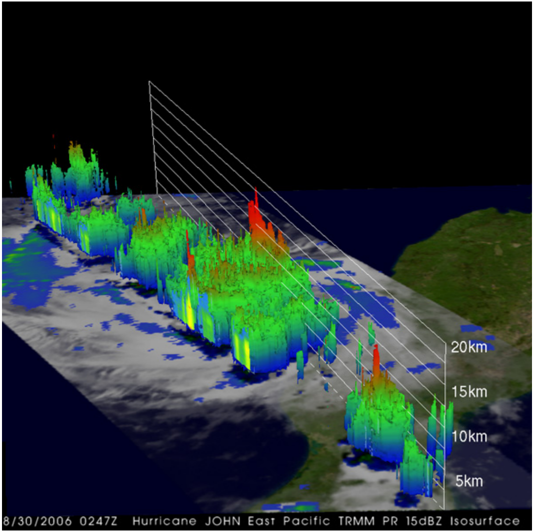


Products - horizontal precipitation rate



Products - vertical precipitation rate



Mission Concept

- CEOS standards for calibration
- Pre- launch calibration for both instruments
- intercalibration for both instruments: Dome-C (75°06' S,123°21' E) with revisit time average 1 day

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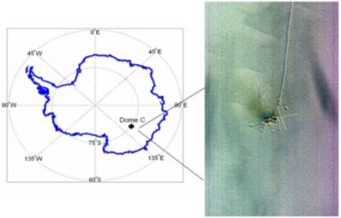


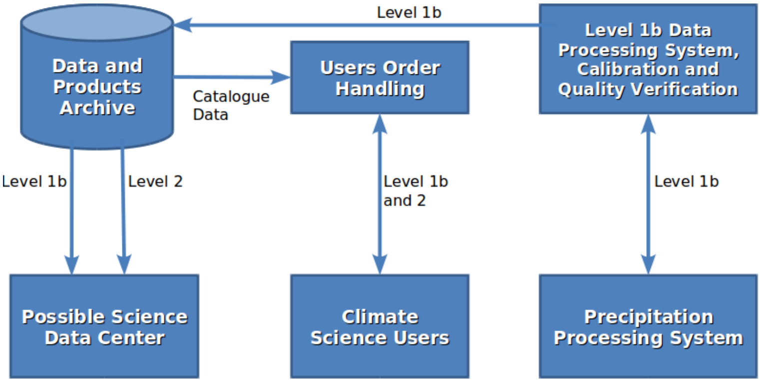
- Relative calibration for both instruments at International Amazon Rainforest Site

Mission Segment - Concept

- One spacecraft in LEO that accomodates two conically scanning instruments
- Polar orbit for non-biased precipitation measurements
- Use of Svalbard groundstation

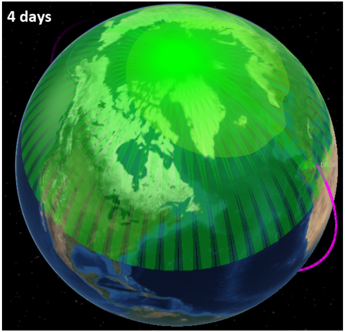
Mission Segment - Data Retrieval

Nominal data downlink every two orbits for retrieval of Level 0 data from the spacecraft.



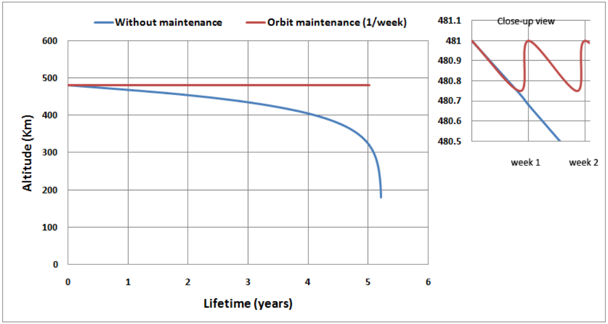
Mission Segment - Orbital parameters

- Type: circular LEO polar orbit
- Altitude: 481 km
- Inclination: 88 deg
- Orbit nodal plane drift: -0.265 deg / day



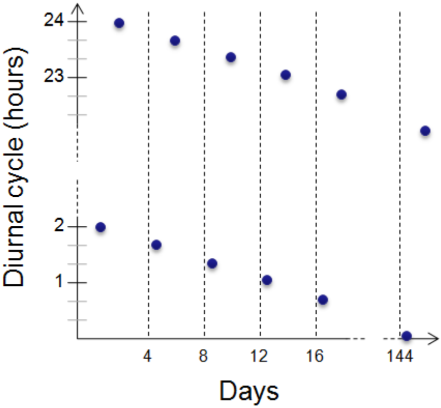
Mission Segment - Orbit maintenance

- Low altitude for improving instruments' performance
- Altitude decrease of 250 meters every week
- Orbit maintenance with Δ V=0.15 m/s every week



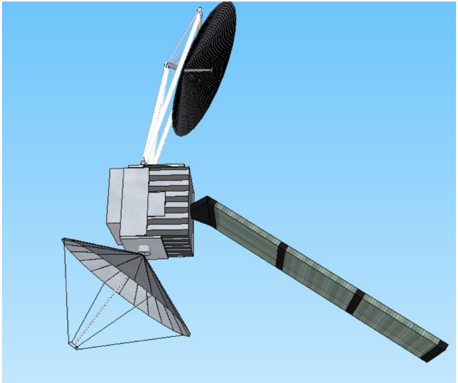
Mission Segment - non-synchronous orbit

- Repeat cycle of ground tracks: 4 days
- Full diurnal cycle: 144 days
- Diurnal cycle time sampling: $\leq$ 20 min (2 observations every 4 days)



Space Segment - Satellite

- Satellite mass: 1150 kg
- Approximate size: 1.6×1.4×1.0 m
- Peak power: 550 W
- Average power: 430 W
- Altitude: 481 km
- Inclination: 88 deg



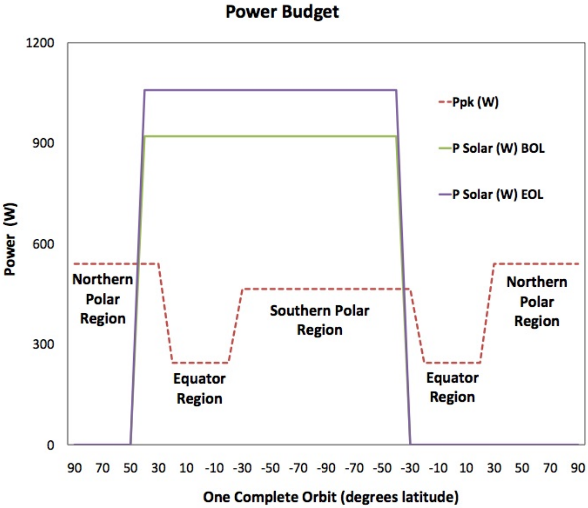
Space Segment - Mass Budget

Subsystem	Mean margin	Mass [kg] x Margin
Payload	20%	294,0
ADCS	5%	36,9
Communications	3%	22,8
OBDH	3%	2,6
PCS	11%	196,2
TCS	15%	32,2
ODCS	11%	186,1
Structure	20%	268,8
Total		**1039,5**
System margin 10%	10%	103,9
System Total		**1143,4**

Space Segment - Satellite

				Orbit Example			
Subsystem	Component	Amount	Total Power of all components when ON [W]	Stand-By Equator Region 30% of Orbit	Northern Polar Region 35% of Orbit	South Polar Region 35% of Orbit	Stand-By mode with Orbit Correction
Payload	Microwave Radiometer	1	112.0	0	112.0	112.0	0
	Doppler Radar	1	85.0	0	85.0	85.0	0
	Antenna Radar motor	1	20.0	20.0	20.0	20.0	20.0
	Antenna Radiometer motor	1	20.0	0.0	20.0	20.0	0.0
ADCS	Reaction Wheel Assembly	3	63.0	63.0	63.0	63.0	63.0
	Reaction Wheel Electronics	1	4.0	4.0	4.0	4.0	4.0
	Magnetorquer	3	13.5	13.5	0.0	0.0	13.5
	Star Tracker	1	8.0	8.0	8.0	8.0	8.0
Communications	Comms Control	1	5.0	5.0	5.0	5.0	5.0
	S-band Transmitter TC	1	4.0	0.0	4.0	0.0	0.0
	S-band Reciever TM	1	1.5	1.5	1.5	1.5	1.5
	X-Band Antenna P/L	1	58.5	0	58.5	0	0
	CPU	1	10.0	10	10.0	10	10
	GPS Receiver	1	12.0	5.0	5.0	5.0	5.0
OBDH	Solid State Recorder	1	5.0	5	5.0	5	5
	PCDU	1	10.0	10.0	10.0	10.0	10.0
PCS	Solar Tracker	1	9.0	9.0	9.0	9.0	9.0
	Solar Array Motor System	2	30.0	30.0	30.0	30.0	30.0
TCS	Radiator	1	20.0	0.0	0.0	0.0	0.0
ODCS	Propulsion	1	40.0	0	0	0	40
	Total		530.5	184.0	450.0	387.5	224.0
			Total + Margin (20%)	220.8	540.0	465.0	268.8
	Notes		Some subsystems have intermittent operation. Can be turned on during low power;Thermal & Propulsion.	Low Power. Instruments on stand by. Comms on stand by.	Max Power is being used. Instruments & comms operational. Orbit control off.	Instruments on. Comms on Stand by.	Stand By mode. With power allowed for propultion system for Orbit correction.

Space Segment - Satellite



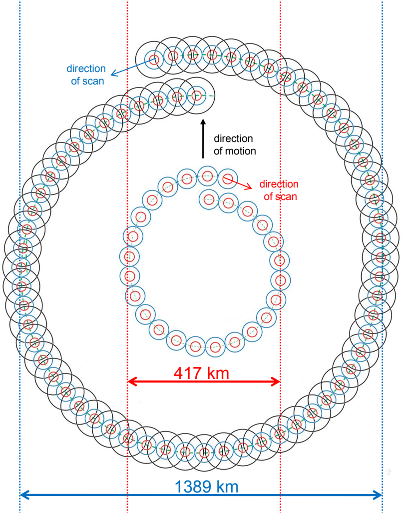
Space Segment - Payload - Instruments

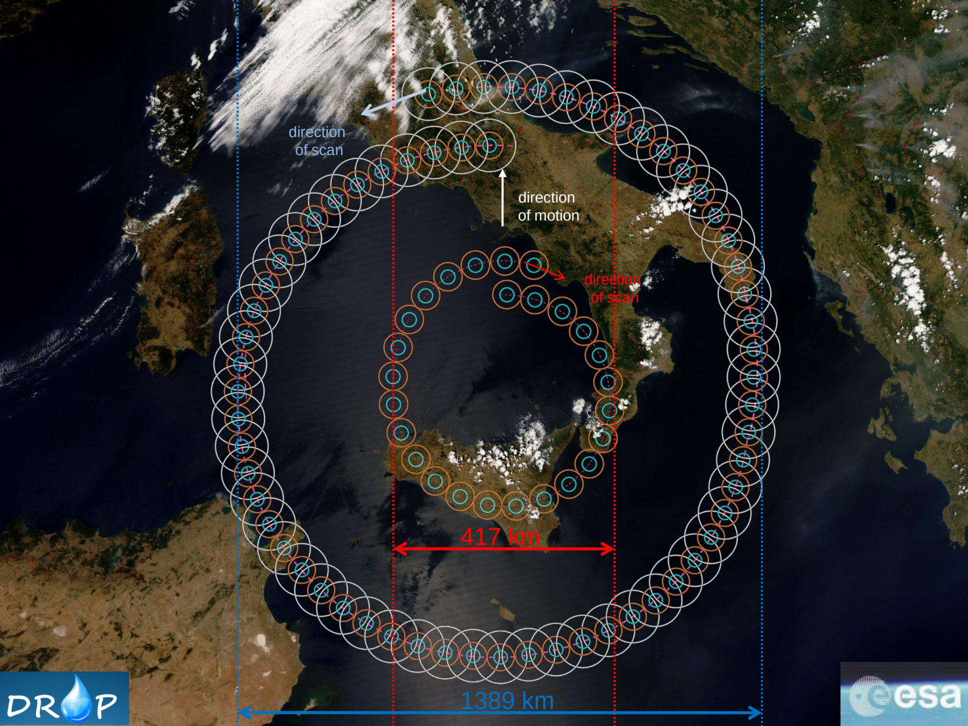
Instruments:

- 7-band Microwave Radiometer (passive instrument)
- Dual-band Doppler Radar (active instrument).

- Antenna size: 1.9 m (active) and 2.0 m (passive)
- Wide swath for the radiometer (1389 km, scan angle: 52.8 deg)
- Smaller swath for the Doppler radar (417 km, scan angle: 23 deg)
- Spatial resolution: 2.0 - 20 km for all used frequencies
- Full coverage across the whole region of interest

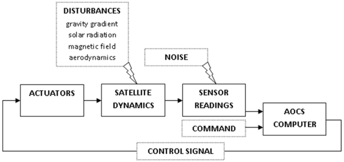
Space Segment - Payload - Footprint




direction
of scan
direction
of motion
direction
of scan
417 km
1389 km

Attitude and Orbit Control System

- Actuators:
  - 3 axis reaction wheel (3 non-coplanar wheels + 1 redundant wheel)
  - Magnetic torquers
  - For accurate pointing (0.01 deg) and propellant conservation
- Sensors:
  - star tracker, sun sensor
  - IMU, MGM, GPS

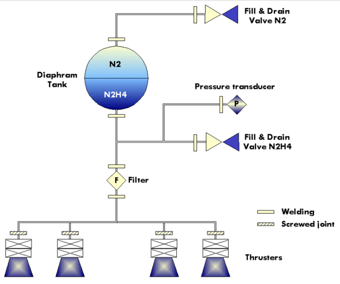


Propulsion System - Propellant Budget

- Delta V budget: ≈ 200
- Estimated I_{sp}: 219
- Propellant: Hydrazine
- Estimated mass of propellant: 100 kg
- Overall weight of the system is lower than other alternatives
- The system is simple and reliable
- Space storable for long periods ($\geq$ 12 years)

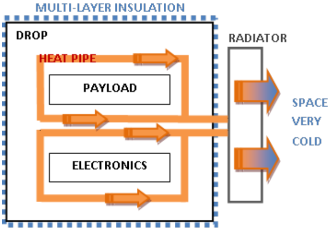
Propulsion System - Dimensions and Schematics

- 4 Thrusters of 2 N (propulsion system redundancy)
- Telemetry: prressure transducer, thermistors in tank and thrusters
- Reliability in front of hydrazine leak - redundant valves



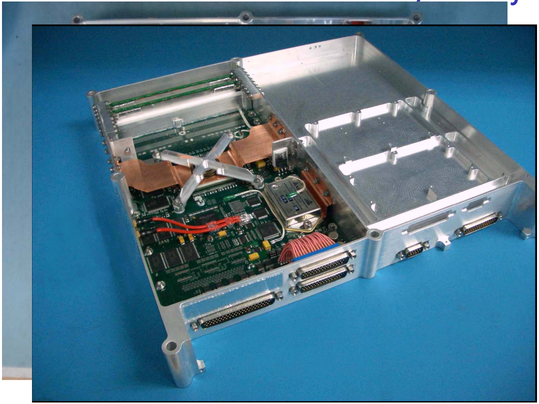
Thermal Control System

- Louvre radiator
- Heat pipes
- Multi layer insulation



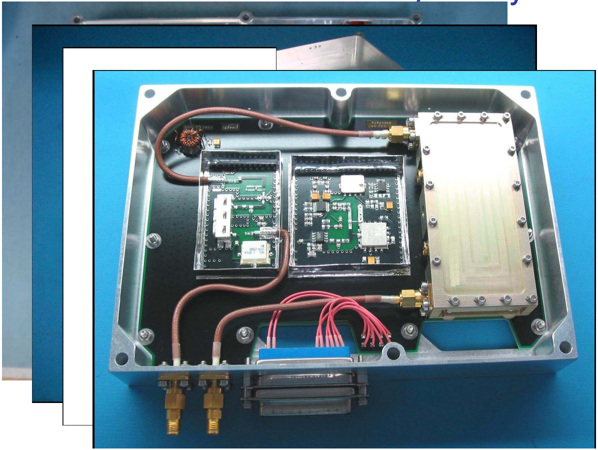
Feasability Study

Feasability Study

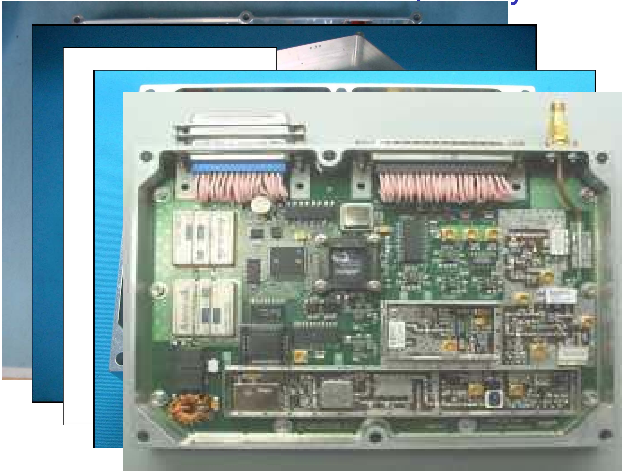


Feasability Study

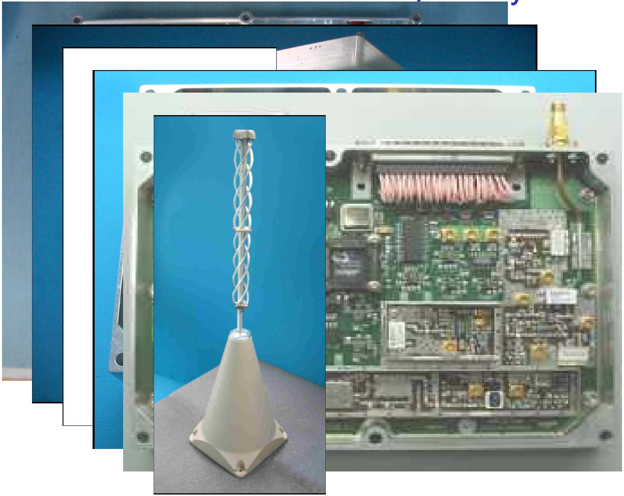
Feasability Study



Feasability Study



Feasability Study

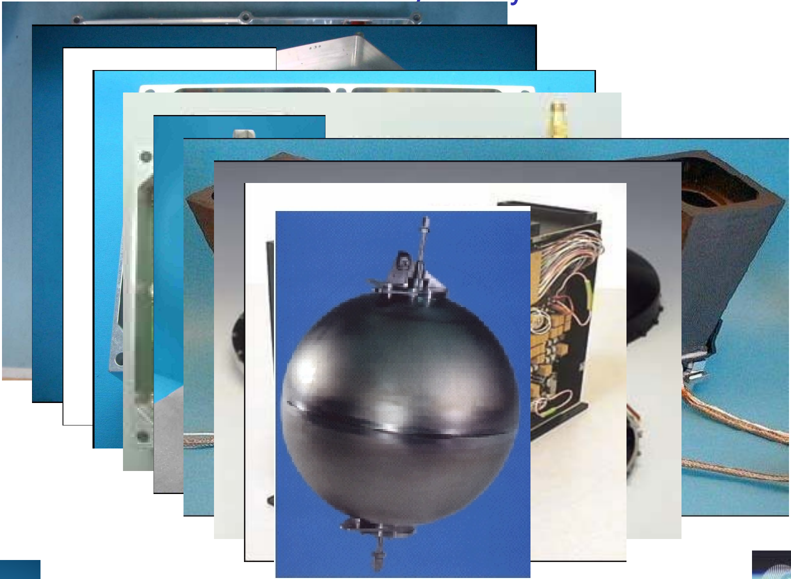


Feasability Study

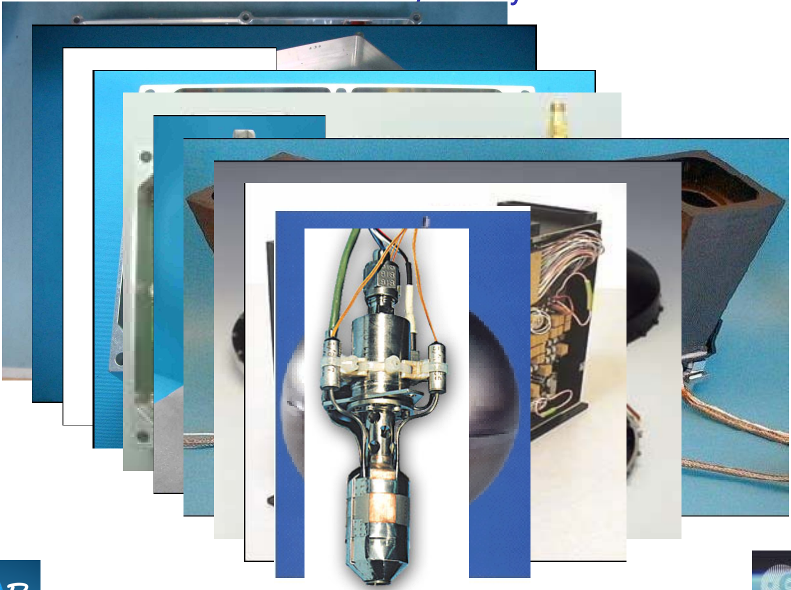
Feasability Study

Feasability Study

Feasability Study



Feasability Study

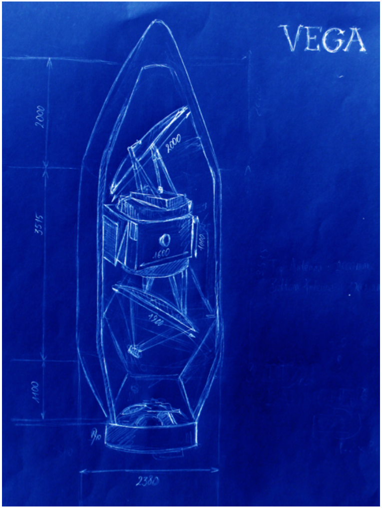


Feasability Study

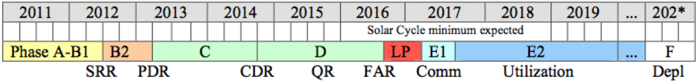
Technology Readiness Level

Component	TLR	References	Implications
rot. Radiometer	6	AASTR	Modifications
rot. Radar	3	Groundbased weather, military radar	Adaptation for Space
LEO dual-spinner	2	none	Simulation, Design, Qualification
Subsystems	8..9	multiple	Minor adaptation
Mechanisms	7..8	multiple	Load adaptation

Launch Segment - Launcher



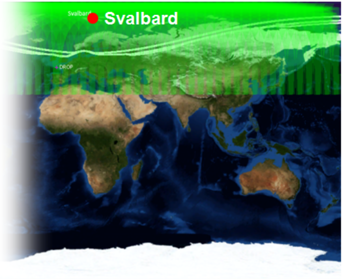
Launch Segment - Mission Schedule



SRR: System Requirements Review
PDR: Preliminary Design Review
QR: Qualification Review
LP: Launch Preparation & Launch

FAR: Flight Acceptance Review
Comm: Commissioning
Depl: Deployment

Ground Segment



SVALBARD

Payload data
TC/TM

BACKUP STATIONS

Kiruna, Spain,
ESA Ground station network

Payload data
TC/TM

GROUND STATION NETWORK

ESOC

ESRIN

ESRIN

Ground Segment - Communication

Type	S-band	X-band
gain	omnidirectional	high-gain
Maximal capacity	8 mbps	100 mbps
Main goal	Telecommand/Telemetry	Data downlink

- Redundancy: S-band can replace X-band partially
- Estimated minimal time for communication per orbit: 2 minutes

Ground Segment - Data handling

- 120 kbps data rate from experimental devices
- 128 megabytes of data per orbit (with redundancy) Storage capacity is enough for a plenty of orbits

Mission Constraints

- Technology
- Risk
- Cost
- Descope

Technology Constraints

- Lifespan of system elements (extended lifetime):
  - Most of black box systems has not more then 7.5 years of lifetime
- Available resolution:
  - Constrained by orbit altitude (drag)
  - Antenna size (launcher cone size)

Risk

Problem	Severity	Probability	Consequences	Mitigation
Solar panels deployment problems	High	Medium	Limited power from batteries, Possible mission failure	Re-deployment action, Early design analysis
Instruments wrong spin rate	High	Low	Measurements inaccuracy, Attitude control problems	Early technology development/testing
Launch delay	Medium	Medium	Lifetime reduction	No mitigation
Transponder un-readiness for absolute external calibration	Medium	Medium	Launch delay, Lifetime reduction	Early technology development/testing
Antenna wrong scanning angle	Medium	Low	Coverage changes, lower signal	No mitigation
Not optimal orbit injection	Low	Low	Lower/higher altitude, Lifetime reduction	Propulsion used

Cost

*The **DROP** mission* *Cost Analysis*	
	approx. price
Satellite (Payload Module, included calibration and Launch campaign)	100M
Instruments (Dual-frequency Doppler radar and Microwave Radiometer)	90M+ 90M
Launcher (VEGA)	35M
Ground segment (Operational costs throughout the nominal life-time (4 years))	20M
Algorithms and Data Processing	2M
Total (+10% contingency)	**~370M**

Descope

OPTION 1: exclude the passive instrument (Microwave Radiometer)

- + reduces weight (30%)
- + reduces power consumption
- + one antenna less
- + smaller solar panel
- + simplified design
- + lower cost
- + no adapted mechanism for launcher needed

- - lose temporal and spatial coverage

Descope

OPTION 2: select a sun-synchronous orbit

- + simplifies power system
- + simplify design
- + reduce size and weight of the mission
- - data will be biased if we pass at the same time above the same region