RainCube: a New Paradigm to Observe Weather Processes

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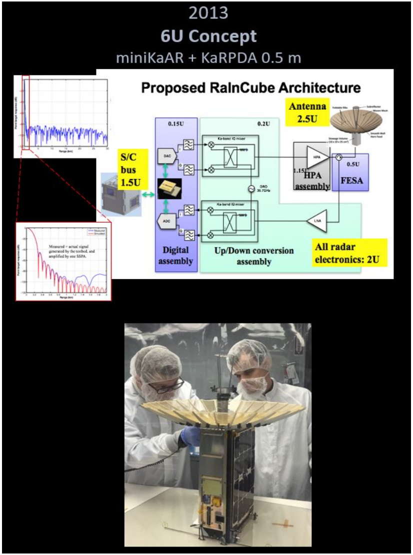
Radar in a CubeSat: PI Dr. Eva Peral, radar/JPL



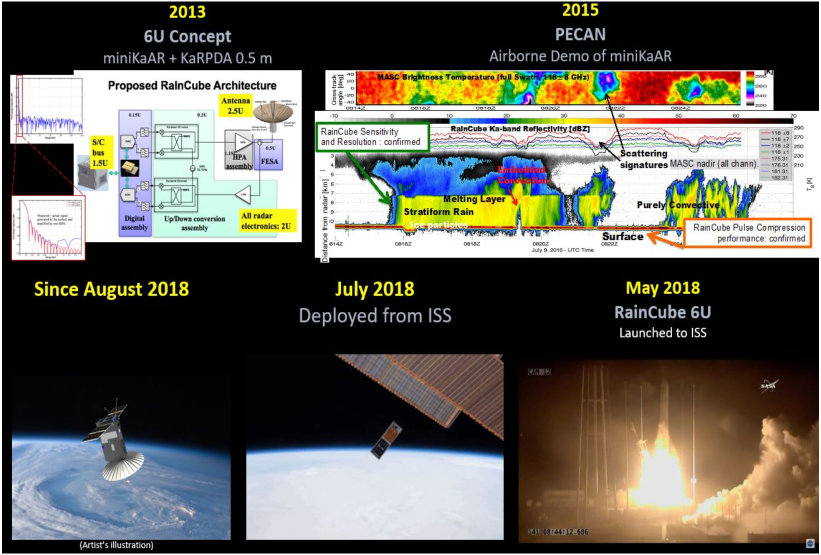
	RainCube
Frequency	35.75 GHz
Antenna size	0.5 m
Sensitivity	13 dBZ
Hor. Resolution	8 km
Range Res	250 m
Beams	1 (nadir)
RF Power	10 W
Processing	Pulse compression

Tech demo objectives

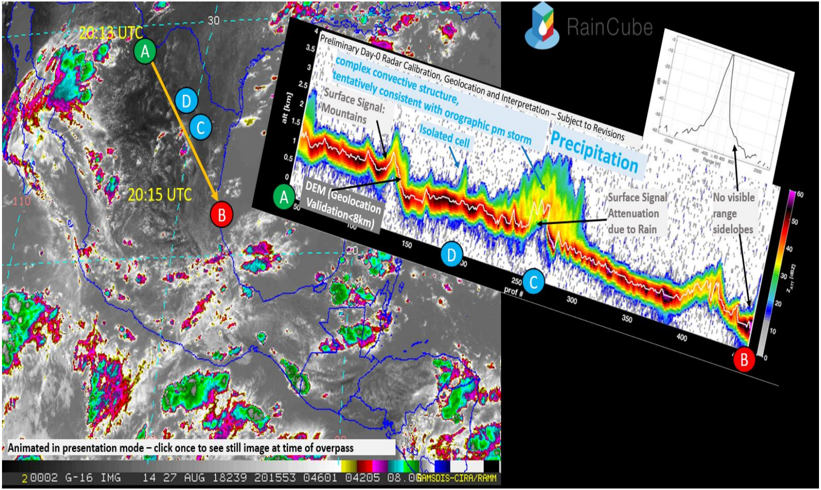
Can such a radar, in LEO (400 km),

- detect precipitation?
- capture the vertical structure of storms?

RainCube: PI Eva Peral, radar/JPL, launch&ops/Tyvak

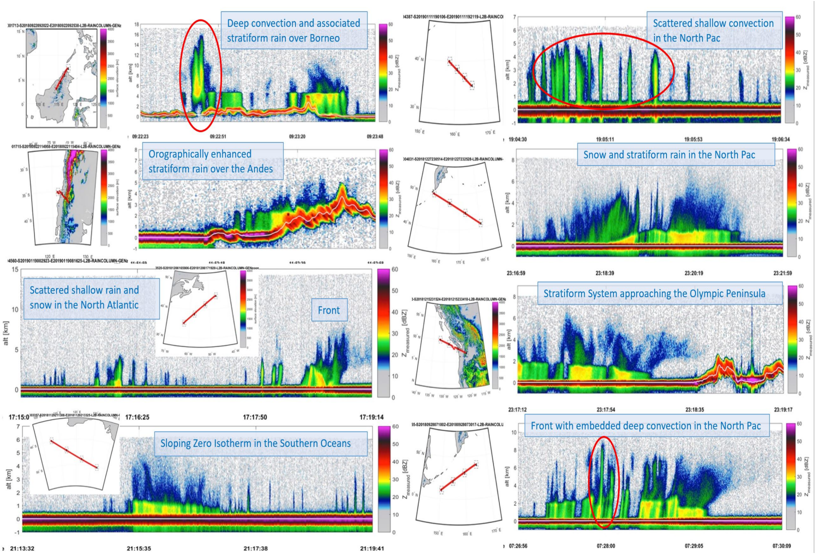


1st detection of rain: 27 Aug 2018, Sierra Madre, Mexico



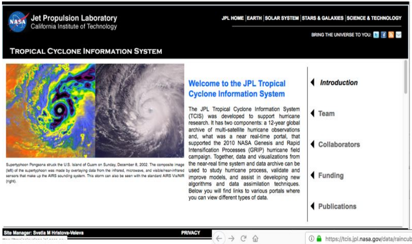
Fast growing orographic precipitation developed shortly before RainCube's pass

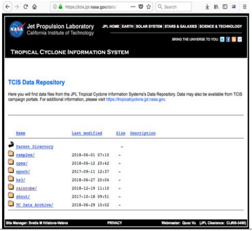
RainCube collection of storms



RainCube data hosted by TCIS portal

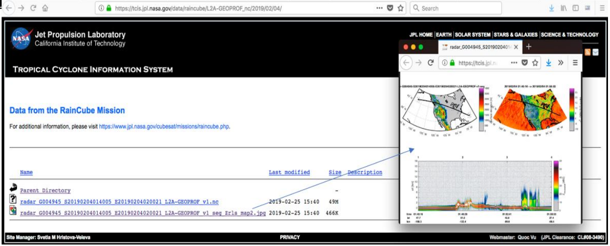
https://tcis.jpl.nasa.gov/data/raincube/





Data Distribution
#P5.1

The Tropical Cyclone Information System hosts RainCube data.
Huge thank you to
PI : **Svetla Hristova-Veleva**,
Site Administrator: **Quoc Vu**,
Data Manager: **Brian Knosp**
L2A are posted (data & browse images).
L2B Data will be made public when QC is satisfactory.
No plan to open L0 and L1 data to the public.



Overview

RainCube: Completed the Primary Objective of the Tech Demo

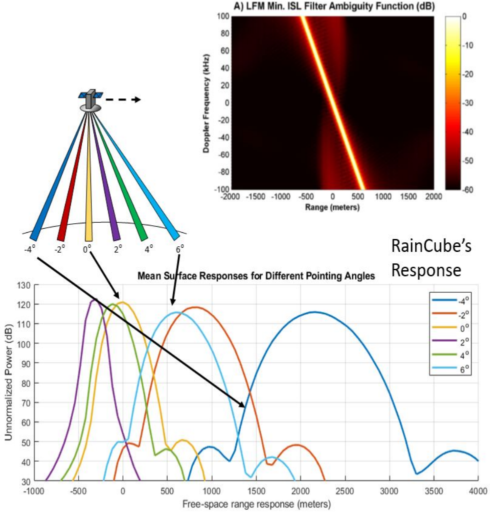
✓ detect rain from a 6U CubeSat

✓ measure the structure of storms from a 6U CubeSat

RainCube: additional objectives:

1. Validate Pointing for geo-location
   - Flat Surface Response (FSR) method
   - Topographic Feature Correlation (TFC) method
2. Augmented measurements
   - Deconvolved measurements
   - Environmental context from reanalysis (MERRA)
3. Calibration and Validation
   - NEXRAD
   - GPM
4. Combined Active-Passive

Flat Surface Response method



Occasional pointing drifts of platform

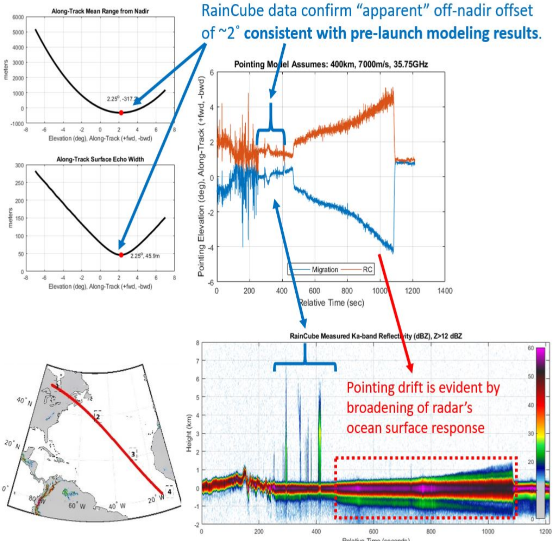
The Doppler shift from the surface
⇒ apparent shift in the range
⇒ broadening of surface response

Advanced modeling predicted that the apparent pointing offset due to Doppler effects should be $\sim 2.24^\circ$ forward for RainCube

R.M. Beauchamp, S. Tanelli, E. Peral, V. Chandrasekar, "Pulse Compression Waveform and Filter Optimization for Spaceborne Cloud and Precipitation Radar,"

in *IEEE TGRS*, vol. 55, no. 2, pp. 915-931, Feb. 2017.

Flat Surface Response method: example Sept. 1st 2019, 11:10:10

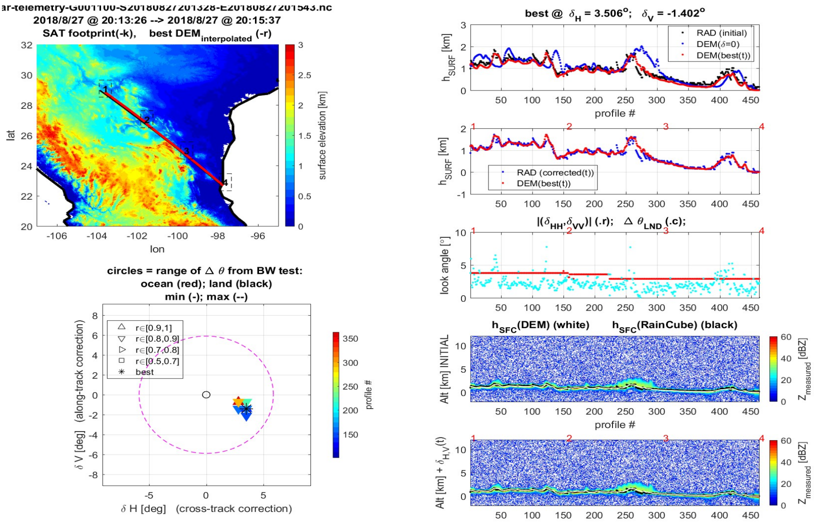


Occasional pointing drifts of platform
⇒ detected clearly within the radar data

⇒ Within $\sim 6^{\circ}$ off-nadir, RainCube processing system can compensate and correct geolocation

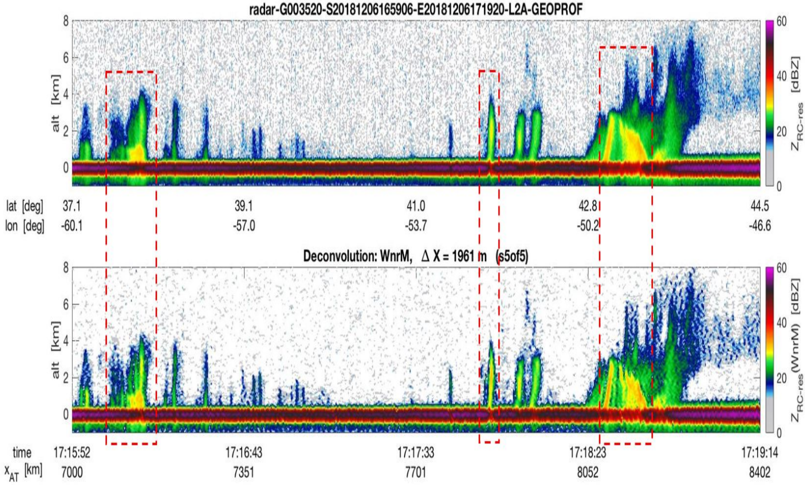
Flat surface response data validated amplitude of off-nadir angle within a fraction of a degree

Topographic feature correlation (TFC) method



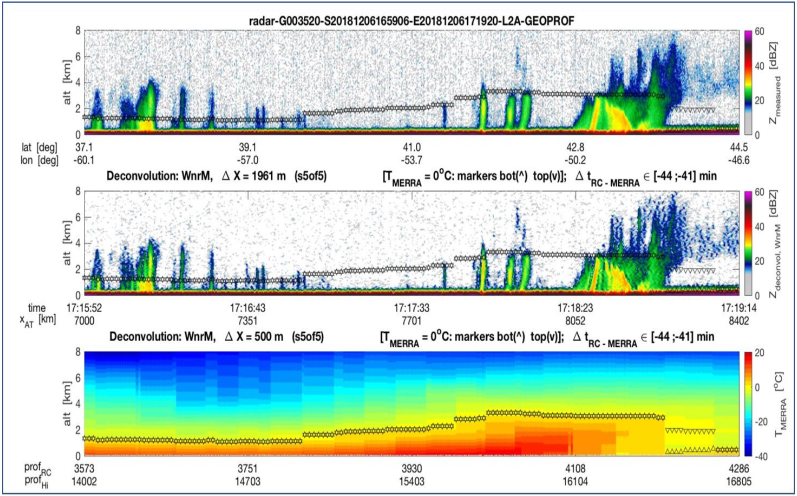
✓ unambiguous estimation of pointing angle

RainCube-deconvolution (8 km footprint, ∼1.9 km sampling, N. Atlantic)



✓ sharper features, better resolution

Storms in their environment (NASA MERRA_3d_inst3_asm, 0.5° × 0.625° × 72)



✓ Environmental context from reanalysis

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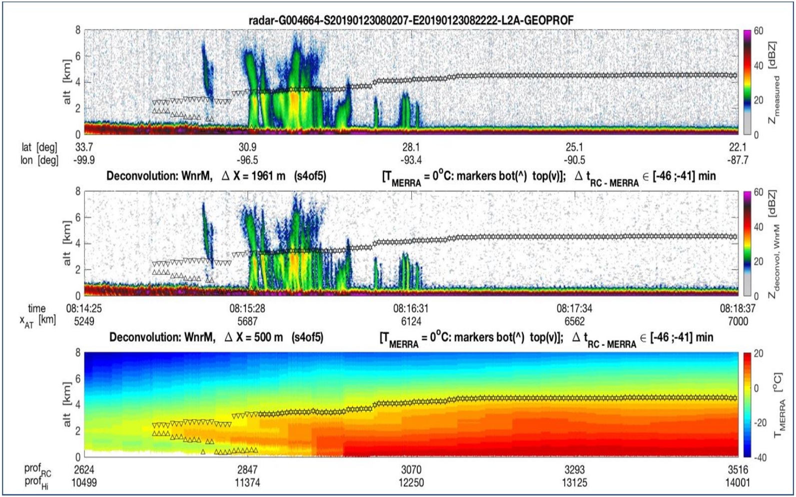
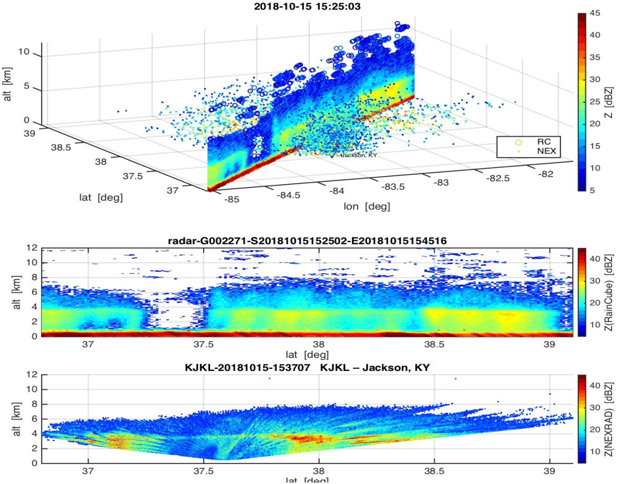


✓ Environmental context from reanalysis

Co-location to NEXRAD (intended for rain rate retrievals)



Complementarity $\neq$ viewing geometries, $\neq$ frequencies

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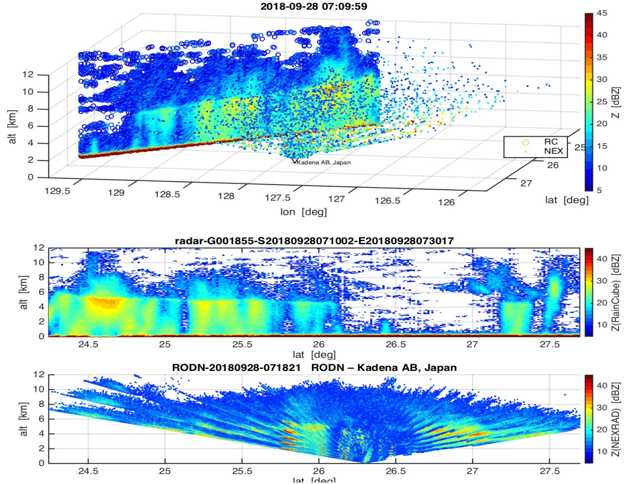
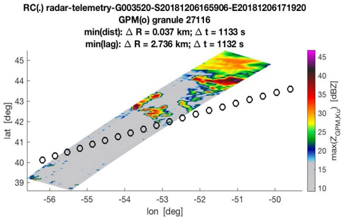
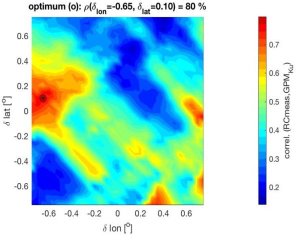
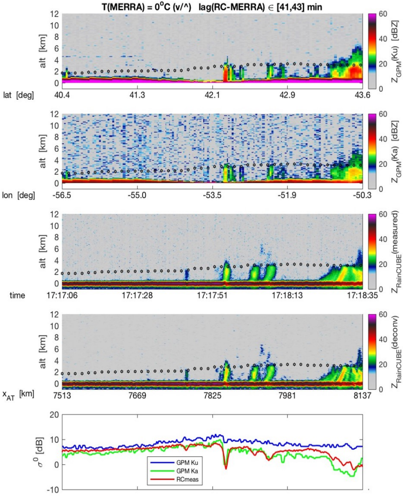


Complementarity $\neq$ viewing geometries, $\neq$ frequencies

RainCube-GPM/DPR (NASA/JAXA, Dec 6th 2018, 16:59:06, N. Atlantic)







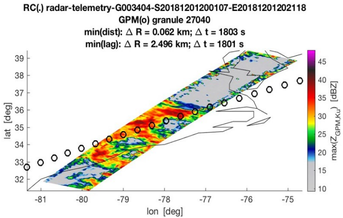
GPM
Ku
Ka

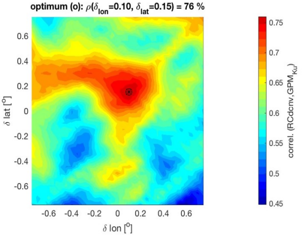
RainCube
measured
deconvol.

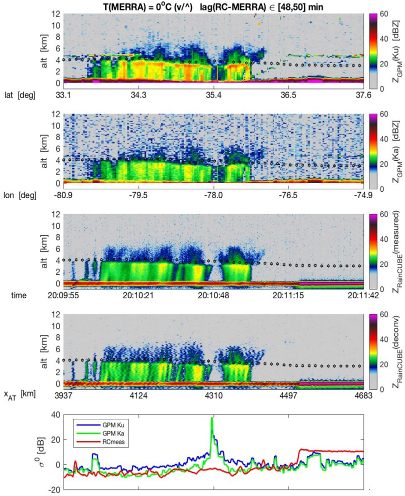
NRCS

✓ 1-to-1 comparisons of Z and σ^0

RainCube-GPM/DPR (NASA/JAXA, Dec 1st 2018, 20:01:07, N. Carolina)







GPM
Ku
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RainCube
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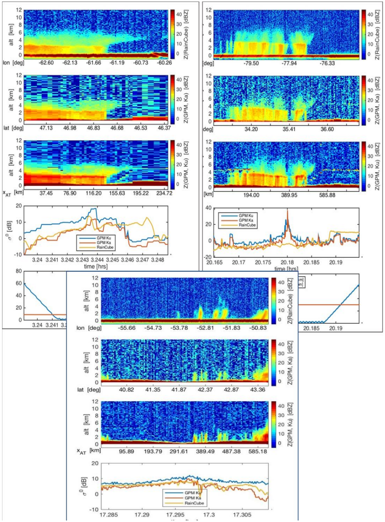
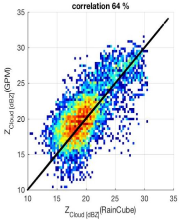
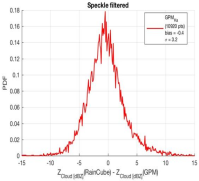
NRCS

✓ 1-to-1 comparisons of Z and σ^0

RainCube vs GPM/DPR-relative calibration validation







Bias RainCube vs DPR Ka

- $|Bias| < 1.5$ dB
- $|Bias| \ll \sigma$

Outcomes:

→ no calibration correction planned for next public release of science data

→ inclusion of this assessment in the product document for user awareness

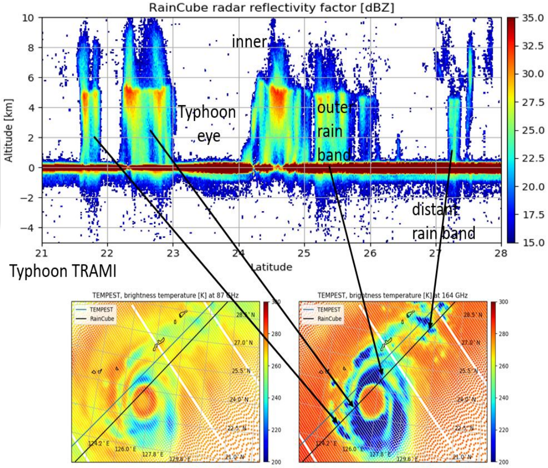
Storm Properties from Active & Passive

2 radar-radiometer datasets

- RainCube + TEMPEST-D
- RainCube + GPM

Engaged GPM Science Team (e.g., Mircea Grecu at GSFC, Alessandro Battaglia at U. Leicester) to develop & evaluate combined radar-radiometer products.

Ongoing effort also at JPL



Images extracted from Battaglia et al. – ESA Living Planet Symposium 2019

Summary

- RainCube: 1^{st} spaceborne precipitation radar in a CubeSat
  1. new implementation of observations of clouds & precipitation
  2. spaceborne C&P radars = RainCube, GPM-DPR, CloudSat
- Mission
  1. prime mission ⇒ demonstrated radar capability
  2. extended mission ⇒ validation of pointing & calibration
     ⇒ grows dataset for science studies
- Scientific community
  - engaged to demonstrate value of combined observations

RainCube (radar in a *CubeSat*) cloud & precipitation profiling: comparable performance to a *subset of GPM-DPR*

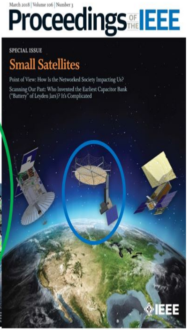
Full potential of RainCube technology hinges upon deployment of multiple units in a (multiple) train(s)

RainCube : What's next ?

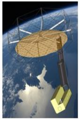
Pre-Decisional Information -- For Planning and Discussion Purposes Only

- Constellation of RainCube's "as is"
  - Analyzing the current dataset to demonstrate the potential and the limitations of the current system in addressing science questions

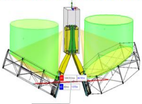
- Constellation with improved antennas & electronics
  - To address a larger set of science questions
  - Development of **technologies** and of **mission concepts** is ongoing
  - **Extension to W and G-band for cloud & precip.**
  - **DPCA** for Doppler, **Larger Size** for improved resolution and sensitivity, **multi-feed** for scanning



RainCube 1.0 m in 12 U



RainCube 1.0 m DPCA in 24U



TENDEG

Ka-band ESTO InVEST and ACT programs

	6U	12 U	50 kg
Antenna size [m]	0.5	1.0	2.0
Sensitivity [dBZ]	15	5-10	0-5
Hor Resolution [km]	8	4	2
Range Res [m]		250	
Beams	1	1-3	1-5
RF Power [W]	10	10-20	10-40

- Constellation with other Radars and Radiometers:
  - A study team in the Earth Science Decadal Survey 2017 will consider RainCube-like constellations for measurements of convection and precipitation
  - Higher frequency versions of RainCube for cloud and water vapor observations
- Planetary applications
  - An evolution of this instrument could support altimetry and cloud and precipitation on planetary targets

Thank you!

For more information:

data: https://tcis.jpl.nasa.gov/data/raincube/

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