SMart Ice Cloud Sensing (SMICES) with a SmallSat Active/Passive Terahertz Instrument

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SMICES Instrument Overview

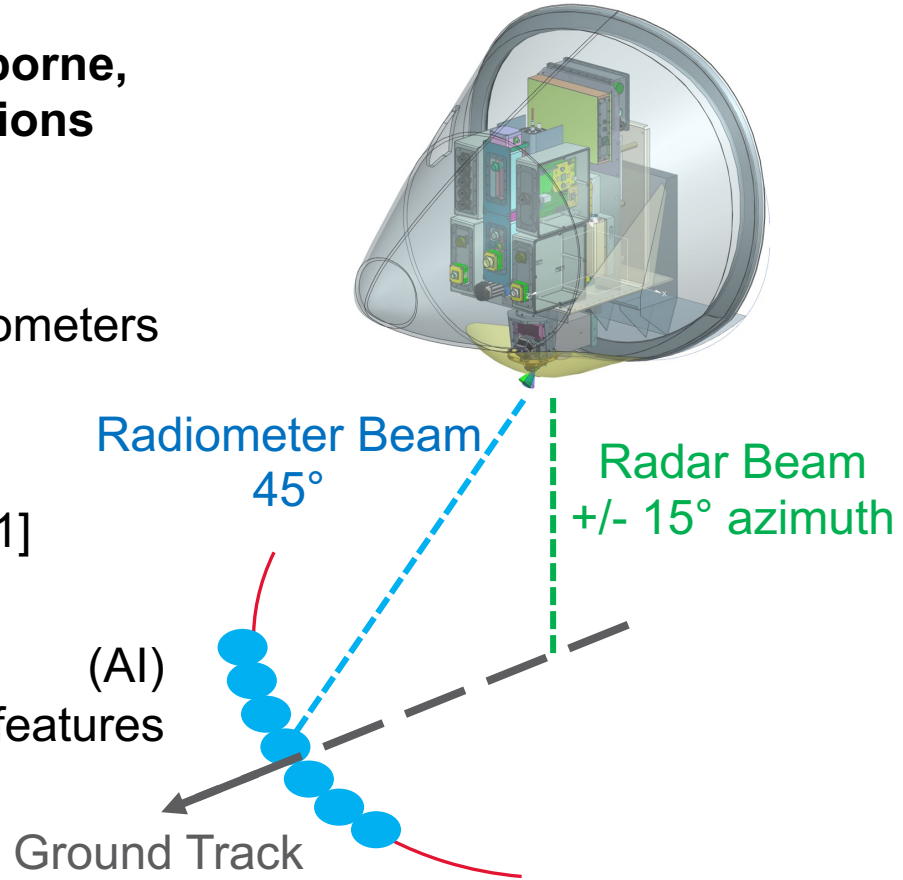
The instrument will be demonstrated airborne, paving the way to future SmallSat missions

SMICES comprises:

- 239 GHz radar
- 250 GHz, 310 GHz and 670 GHz radiometers
- 380 GHz sounder

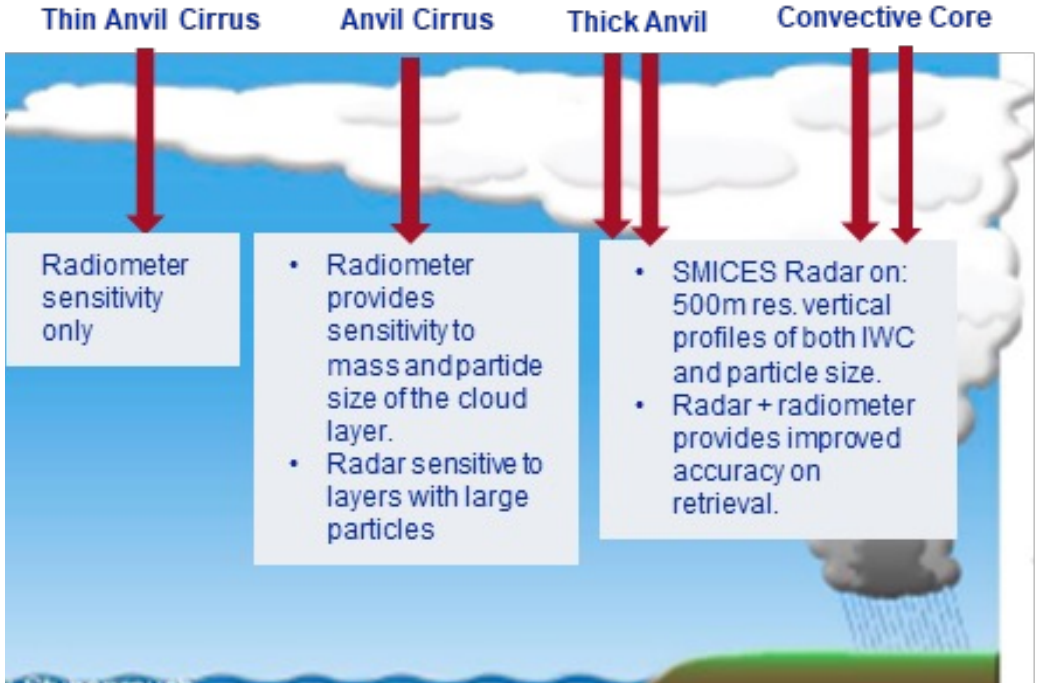
SMICES features:

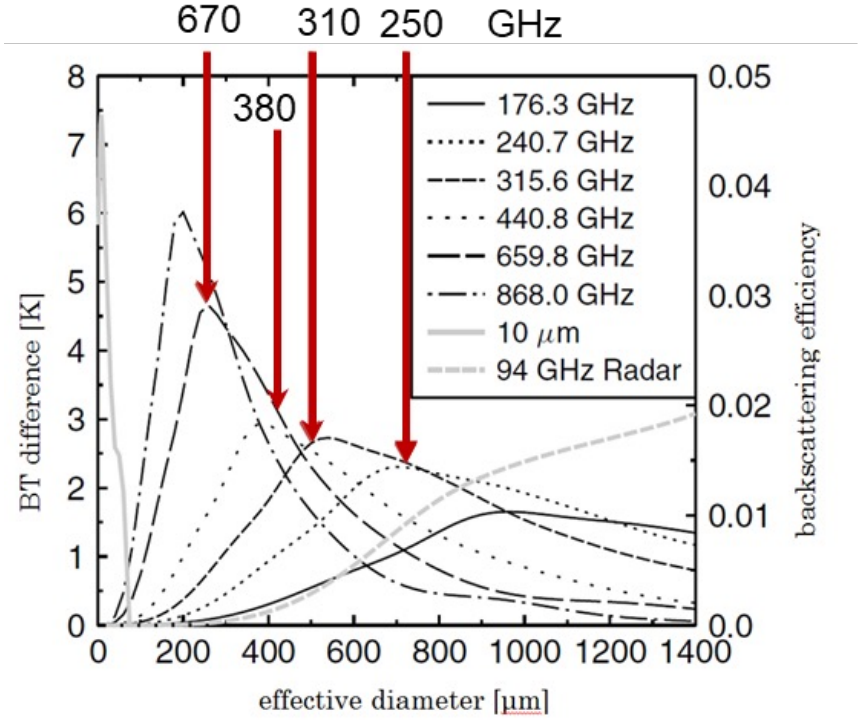
- Novel terahertz receiver architecture [1]
- 1/f noise mitigation technique [2]
- On-board artificial intelligence (AI) controller detects radiometric features to intelligently control the radar [3-4]



SMICES Science Objectives

- Active/passive instrument with a 239 GHz radar for active cloud ice mapping
  - Observations of a cloud system with broadband radiometer channels
- On-board smart operation for more power-efficient and enhanced science return





SMICES AI Benefits

Earth Science Benefits

- High-resolution vertical structures of ice cloud microphysics enabled by power-efficient active-passive measurements
- Maximized science return on deep convective cloud processes with “Smart” targeting.
- “Stare at deep convective cell” – unique overflight measurements of rapid temporal evolution of storms: 1 second resolution for several minutes

AI enables collection of convective storm data at 20% duty cycle / reduced swath by “smart” targeting

Mission Benefits

- Major power savings on SmallSat resources
- *Significant* reduction in average power consumption of the 50 W radar at 239 GHz
- Thus, significant average total power reduction (see table below)

Preliminary power budget

DC Power (W)	Radiometer	Radar	AI Controller	Total
Peak	16	361	0	377
25% Radar Duty Cycle	16	186	0	202
SMICES (AI Control)	16	**37**	7	**60**

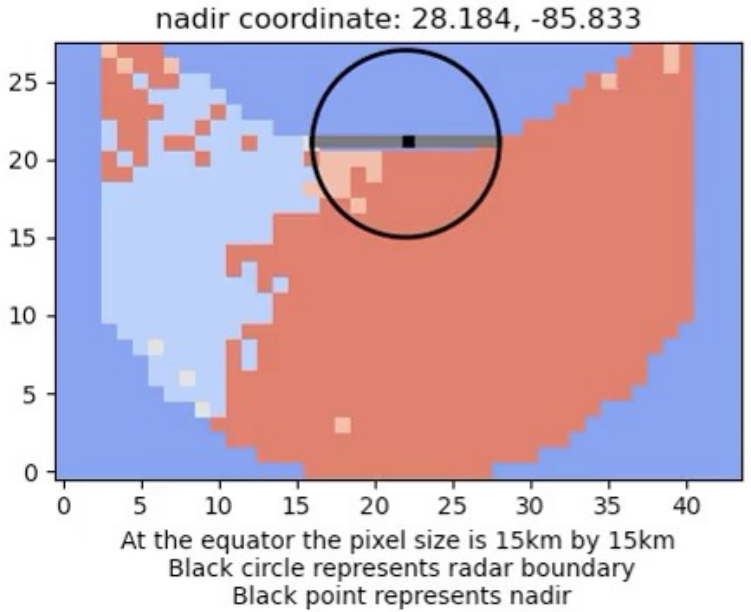
Smart Controller: Radar Autonomy

Orbital Simulation

- Radiometer Swath: 60°, 716 km length
- Radar: 15°, 195 km Swath diameter
- Radar Footprint: 4 km
- Orbital Altitude: 400 km
- Feature Altitude: 10 km

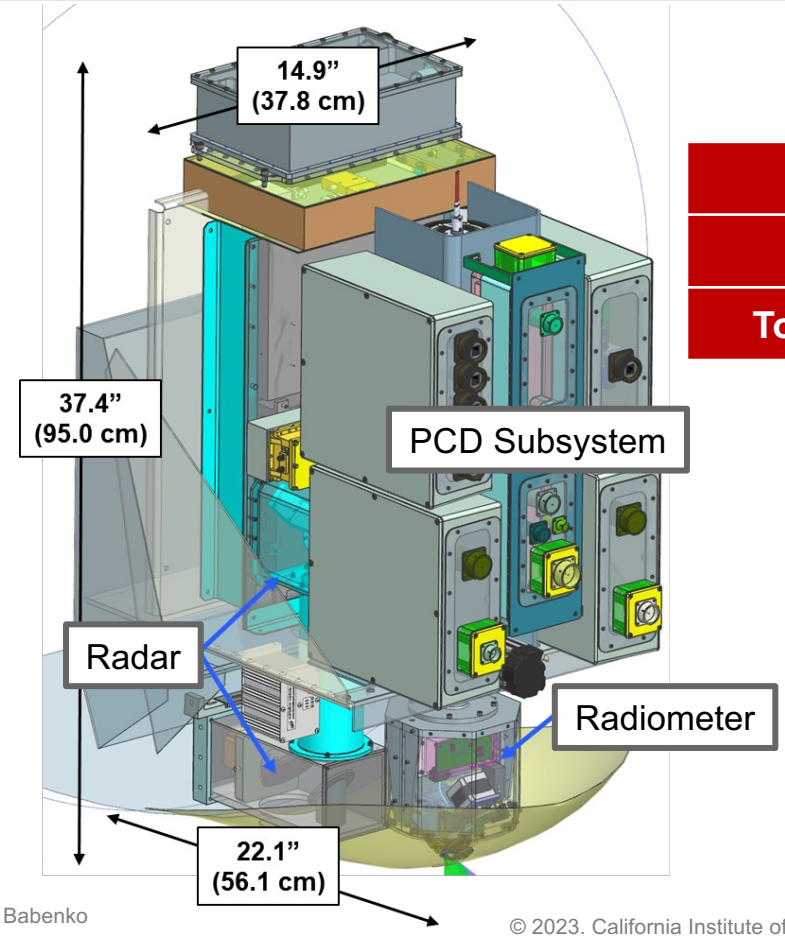
Airborne Simulation

- Radiometer Swath: 60°, 10 km length
- Radar Swath: 40°
- Radar Footprint: 100 m
- Airborne Altitude: 15 km
- Feature Altitude: 10 km



Dark blue pixels signify locations analyzed by the autonomous radar [3]

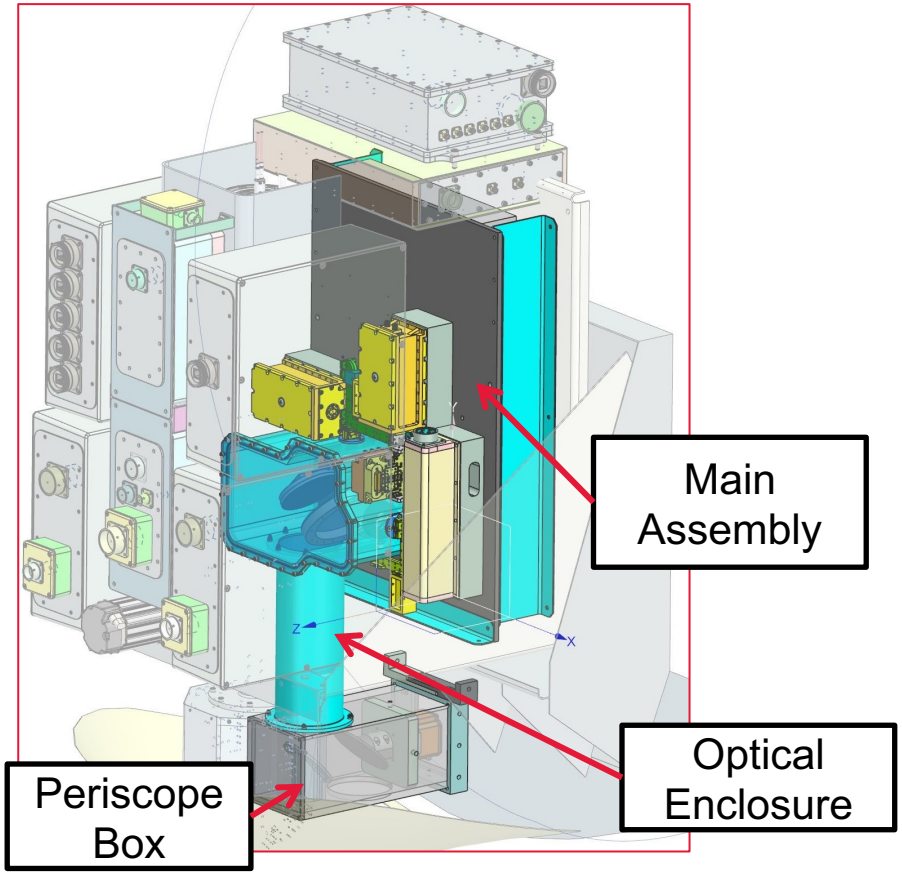
SMICES SWaP Summary



Total Size	**37.8 cm x 95.0 cm x 56.1 cm**
Total Weight	**79.8 kg**
Total Power with AI	**60 W**

	Power, Control, and Data (PCD) Assembly
Size	**13.9”L x 12.0”W x 21.9” H**
Weight	**29.3 kg (total)**

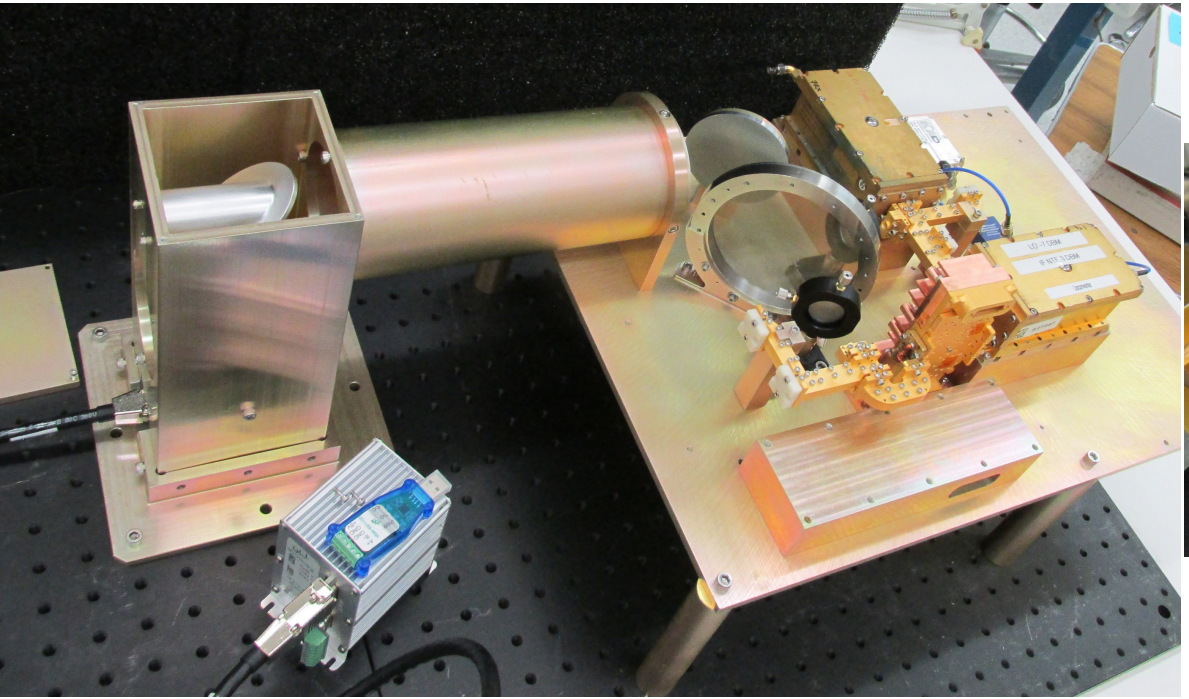
SMICES 239 GHz Radar SWaP



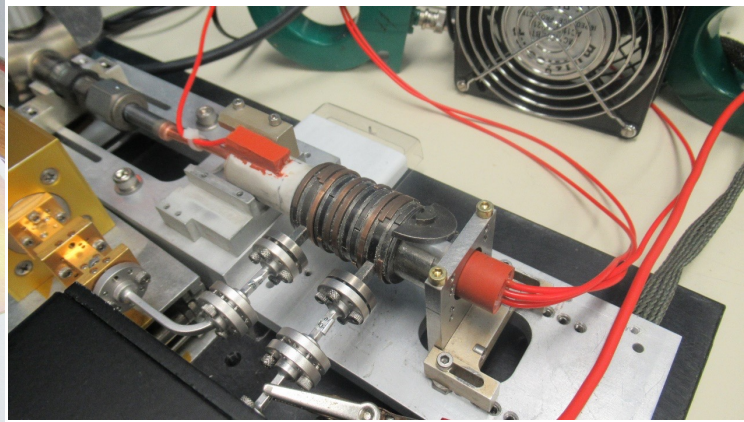
Size	14.0”L x 10.6”W x 36.6” H
Weight	34.8 kg (total) 32.6 kg (in nose cone) 2.2 kg (in cabin)
Power (nom)	185 W

SMICES 239 GHz Radar Assembly

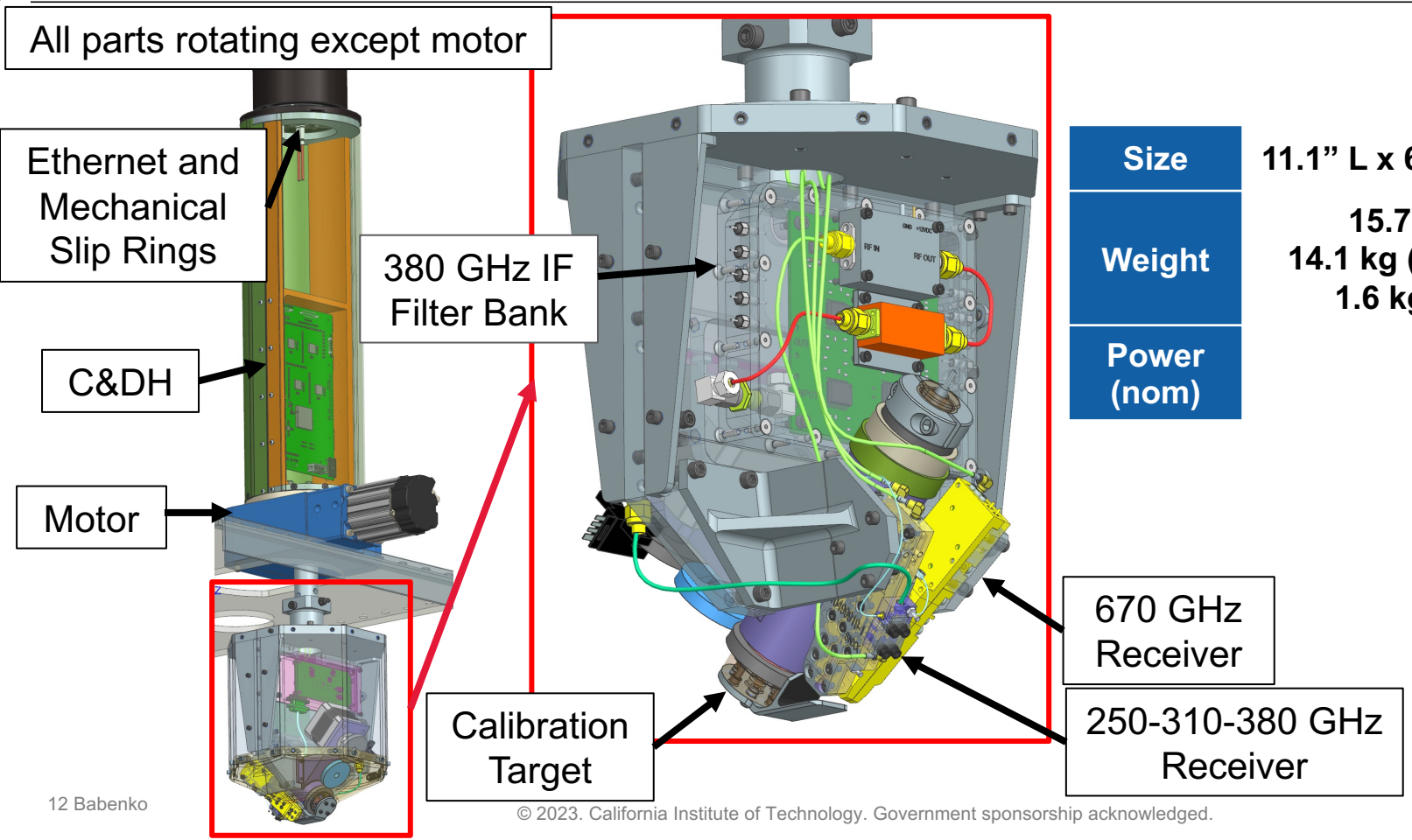
- Radar front-end assembled on the bench
- Set up for front-end TX and RX testing through optics



239 GHz TWT with Magnets
(ESTO ACT-20 and AITT-19)

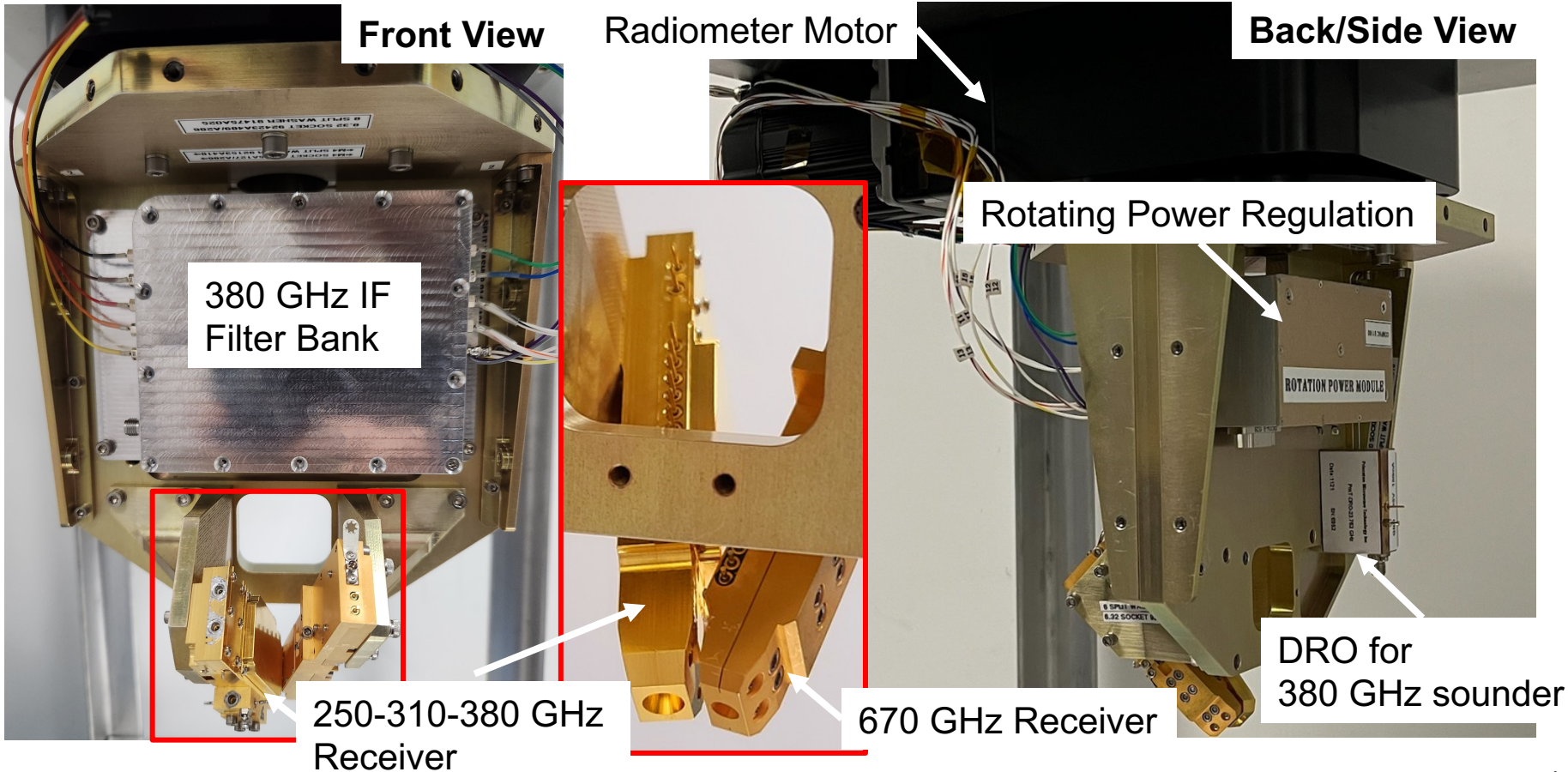


SMICES Radiometer SWaP



Size	11.1” L x 6.6” W x 33.5” H
Weight	15.7 kg (total) 14.1 kg (in nose cone) 1.6 kg (in cabin)
Power (nom)	23 W

SMICES Radiometer Assembly



Conclusions

- The Smart Ice Cloud Sensing (SMICES) instrument will provide high-resolution, accurate measurements of upper-tropospheric/lower stratospheric cloud ice particle size and water vapor profiles
- SMICES will use autonomous operational capabilities enabled by an on-board AI controller
- AI processor will use 250/310/670 GHz radiometer and 380 GHz sounder measurements to control the 239 GHz radar measurements
- Integration and testing of the instrument are to be completed by the end of 2023
- An airborne demonstration is planned for early 2024 on a Northrop G-II aircraft

References

1. X. Bosch-Lluis et al., "Smart Ice Cloud Sensing (SMICES): An Overview of its Submillimeter Wave Radiometer," IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, Kuala Lumpur, Malaysia, 2022, pp. 4296-4299, doi: 10.1109/IGARSS46834.2022.9883671.
2. C. M. Cooke et al., "A 670 GHz Integrated InP HEMT Direct-Detection Receiver for the Tropospheric Water and Cloud Ice Instrument," in IEEE Transactions on Terahertz Science and Technology, vol. 11, no. 5, pp. 566-576, Sept. 2021, doi: 10.1109/TTHZ.2021.3083939. **2023 IEEE Best paper award**
3. Swope, J et al. Using Intelligent Targeting to increase the science return of a Smart Ice Storm Hunting Radar. In *International Workshop on Planning & Scheduling for Space (IWPSS)*, July 2021. CL21_3037.pdf - JPL Open Repository (nasa.gov)
4. M. Ogut et al., "Autonomous Capabilities and Command and Data Handling Design for the Smart Remote Sensing of Cloud Ice," IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, Kuala Lumpur, Malaysia, 2022, pp. 7119-7122, doi: 10.1109/IGARSS46834.2022.9883491.

Thank you!

https://en.wikipedia.org/wiki/Grumman_Gulfstream_II#/media/File:Ng-GII-bams-N82CR-070709-01-16.jpg

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