New National Capability in NIMR: Rational, Development and Application of Meteorological Sensors for HALE UAV

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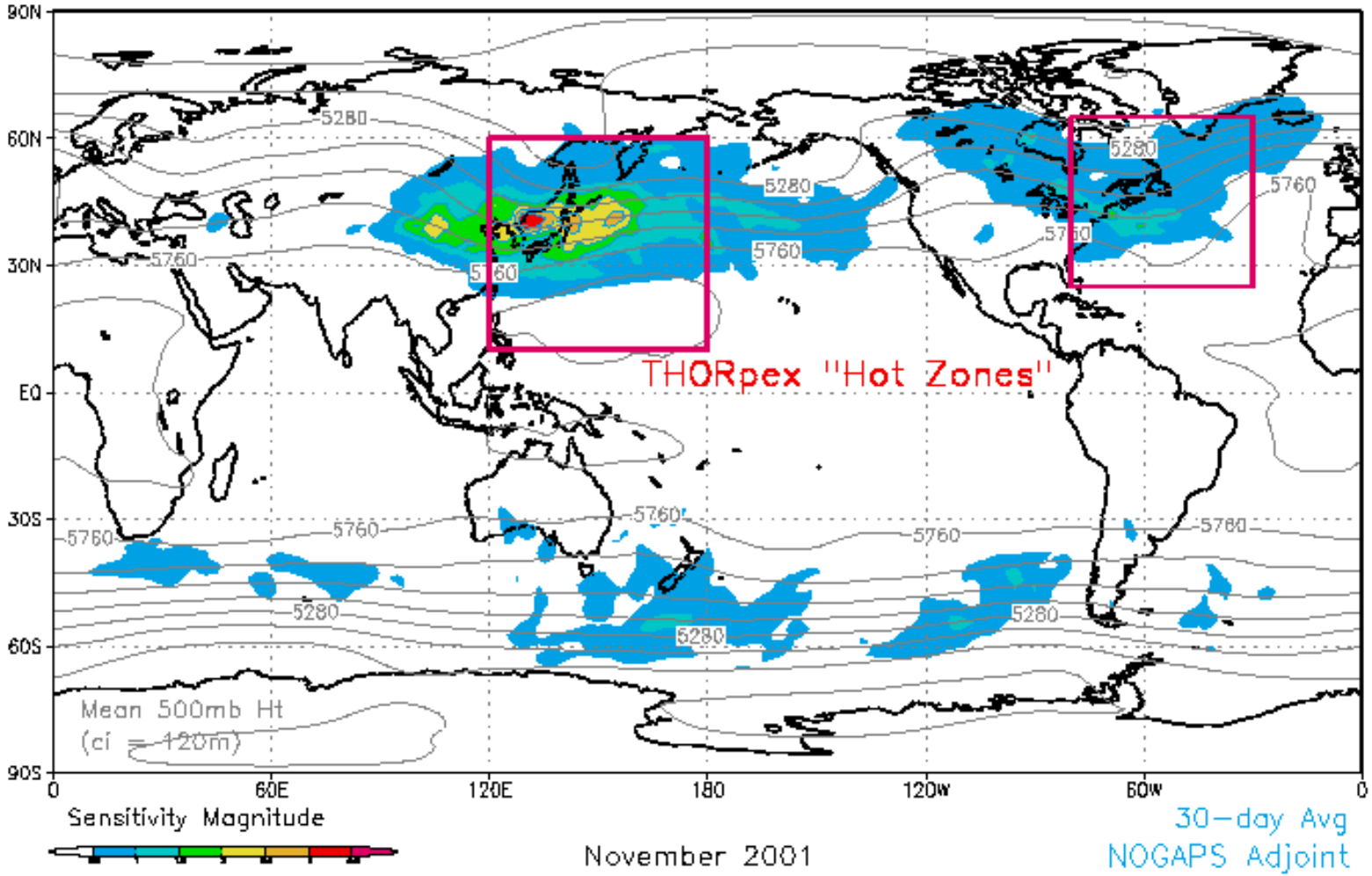
CHAISR
Compact High Altitude Imager & Sounding Radiometer

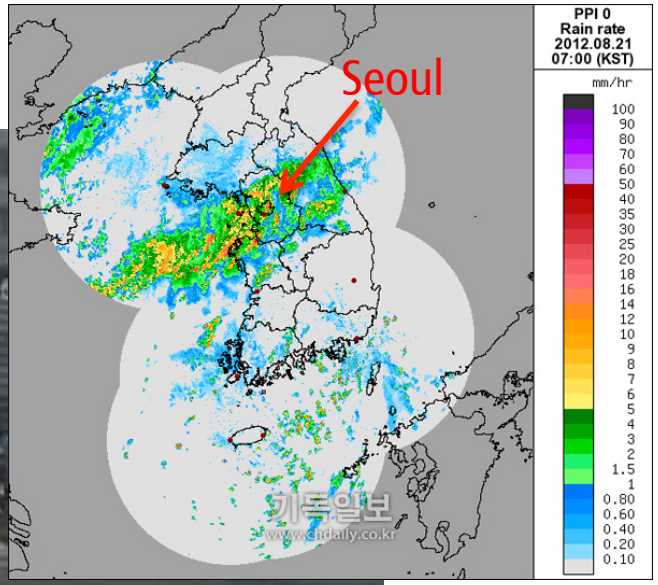
Regional significance

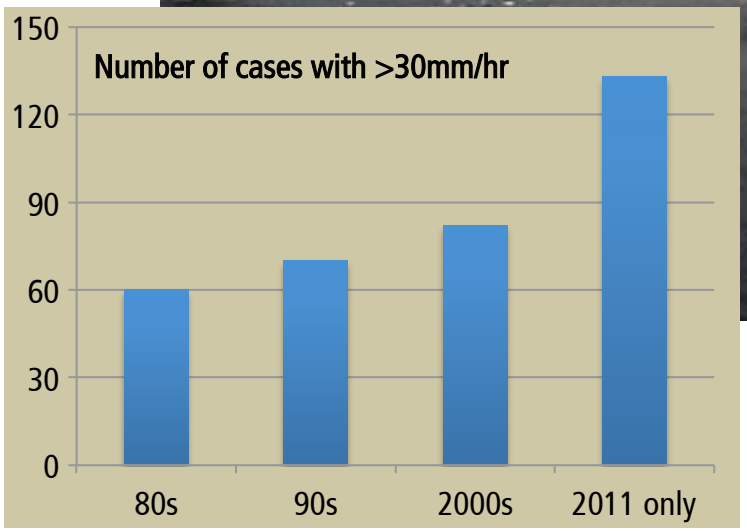


THORPEX-Pacific Asian Regional Campaign (T-PARC), THORPEX (The Observing-System Research and Predictability Experiment)

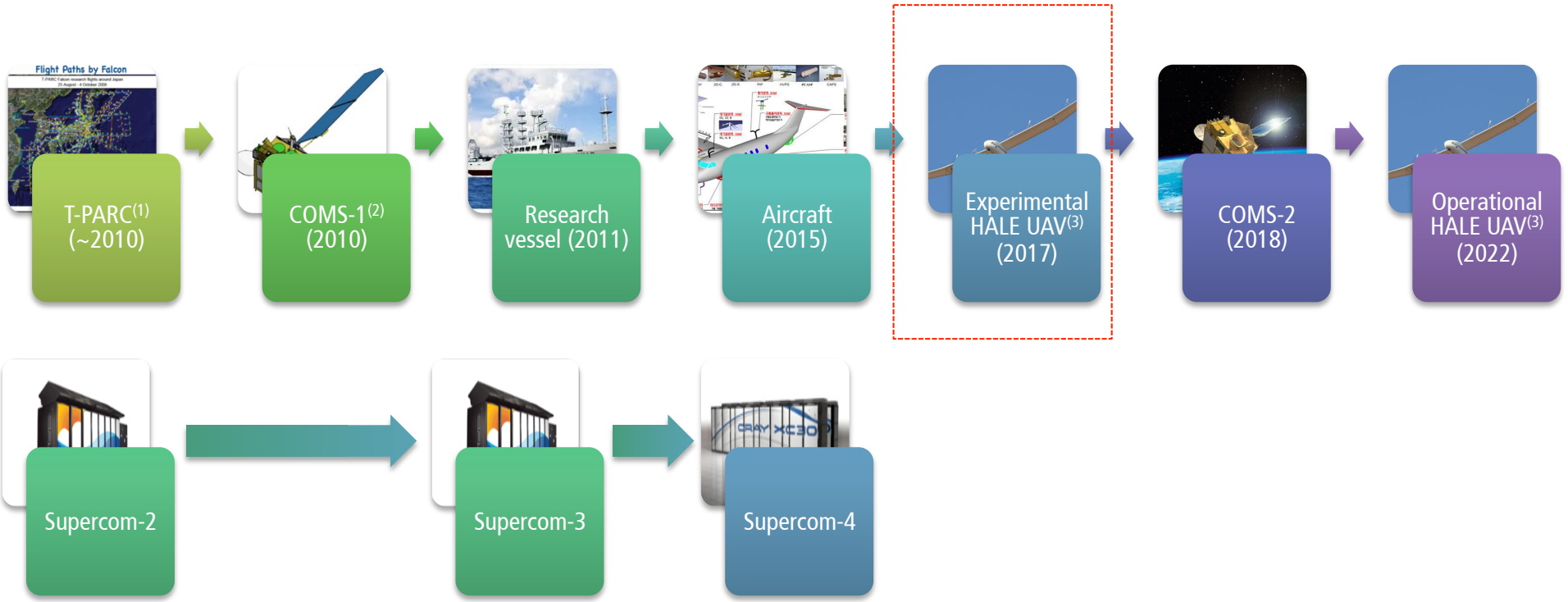
Regional significance

- Torrential rains



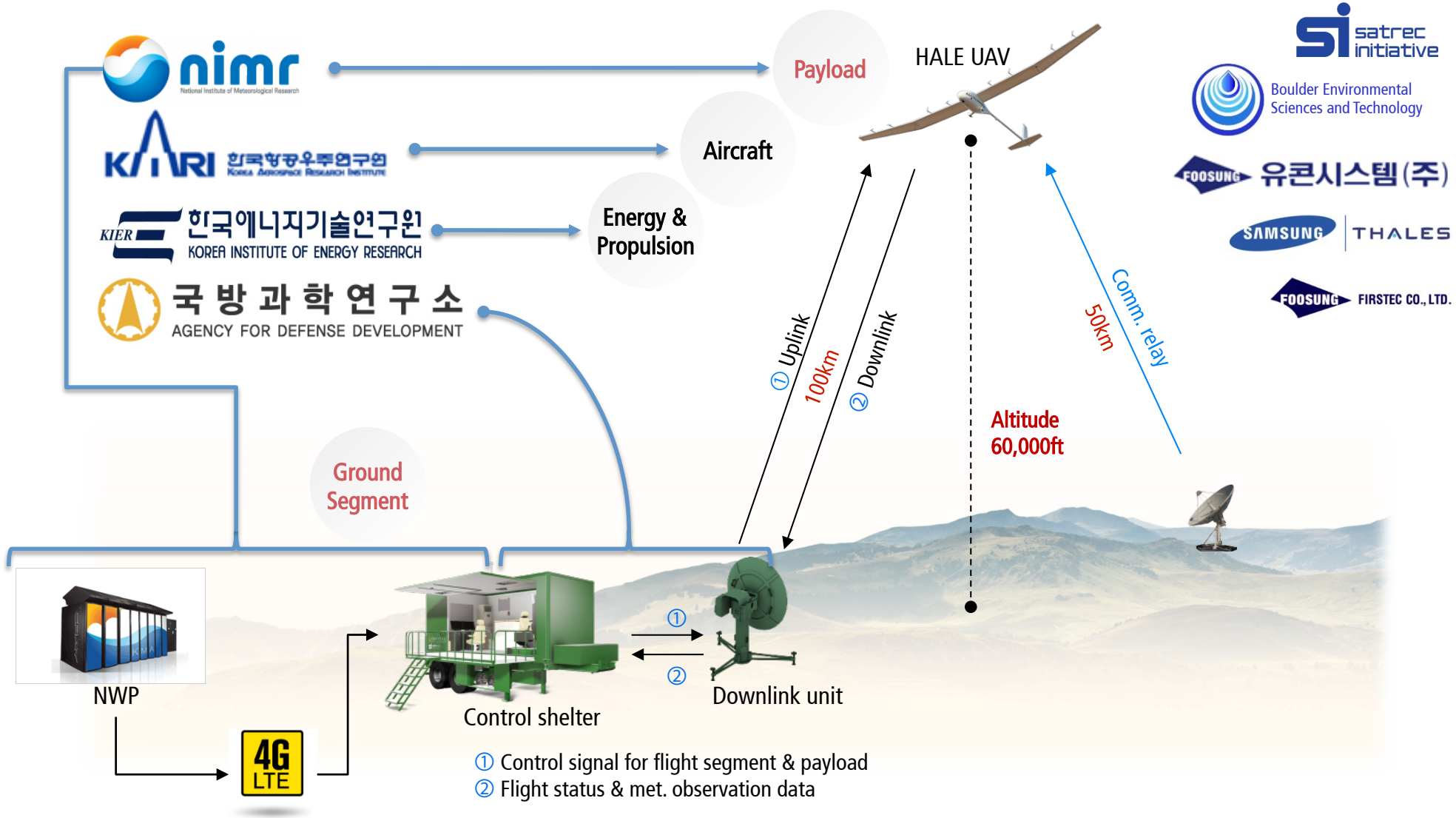


National Capability in KMA/NIMR



(1) THORPEX-Pacific Asian Regional Campaign (T-PARC), THORPEX (The Observing-System Research and Predictability Experiment)
(2) Communication, Ocean and Meteorological Satellite
(3) High Altitude Long Endurance Unmanned Aerial Vehicle

The "HyBird"

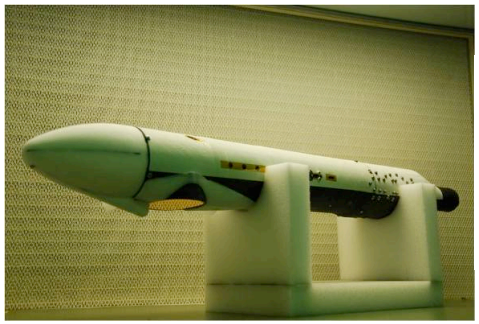

nimr
National Institute of Meteorological Research
KARI 한국항공우주연구원 Korea Aerospace Research Institute
KIER 한국에너지기술연구원 KOREA INSTITUTE OF ENERGY RESEARCH
국 방 과 학 연 구 소 AGENCY FOR DEFENSE DEVELOPMENT
Payload
Aircraft
Energy & Propulsion
HALE UAV
① Uplink
100km
② Downlink
Comm. relay
50km
Altitude
60,000ft
Ground Segment
NWP
4G LTE
Control shelter
①
②
Downlink unit
① Control signal for flight segment & payload
② Flight status & met. observation data
satrec initiative
Boulder Environmental Sciences and Technology
FOOSUNG 유콘시스템(주)
SAMSUNG THALES
FOOSUNG FIRSTEC CO., LTD.

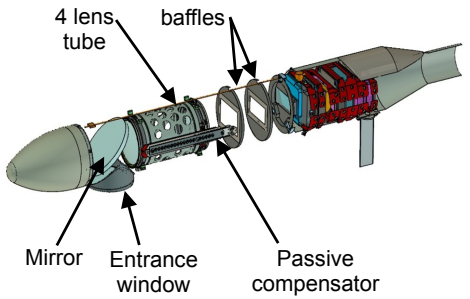
Comparable instruments

- HAMSR (High Altitude MMIC Sounding Radiometer)
- Developed for Global Hawk
- Observation range
  - Up to around 20 km altitude
  - 2~3 km vertical resolution
  - ~ 2 km horizontal resolution
  - ~ 40 km wide swath
- Frequencies of microwave radiometer
  - 8ch @ 50GHz: primary T
  - 10ch @ 118GHz: secondary T
  - 7ch @ 183GHz: Water vapour
- Accuracy
  - Calibrated: 0.2~0.4K (Abs. 0.5K)
  - Processed: <0.2K or 1.5~2%W

- MEDUSA (Monitoring Equipment and Devices for Unmanned Sy stems at high Altitude)
- Developed by VITO, Belgium, through ESA
- Photogrammetric camera
  - FOV: +/- 5.2 degrees
  - Total weight < 2 (to 3) kg
  - Length of the payload < 1m
  - Storage temp.: -70°C
  - Low pressure: 60 mbar
  - Power consumption < 50 W

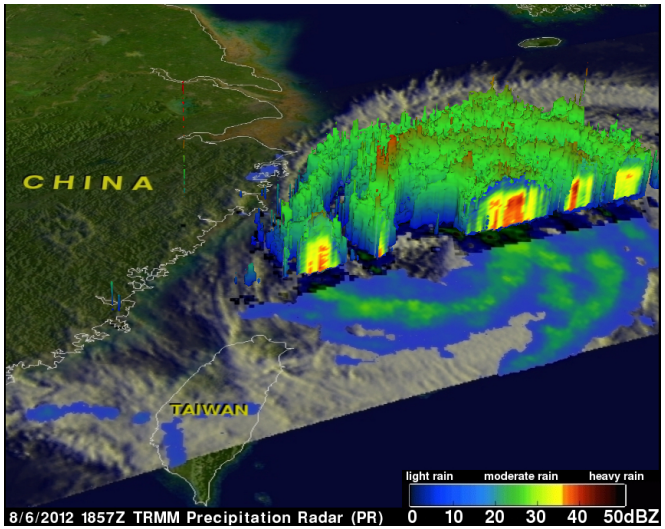
HAMSR about to be installed. Courtesy NASA JPL.



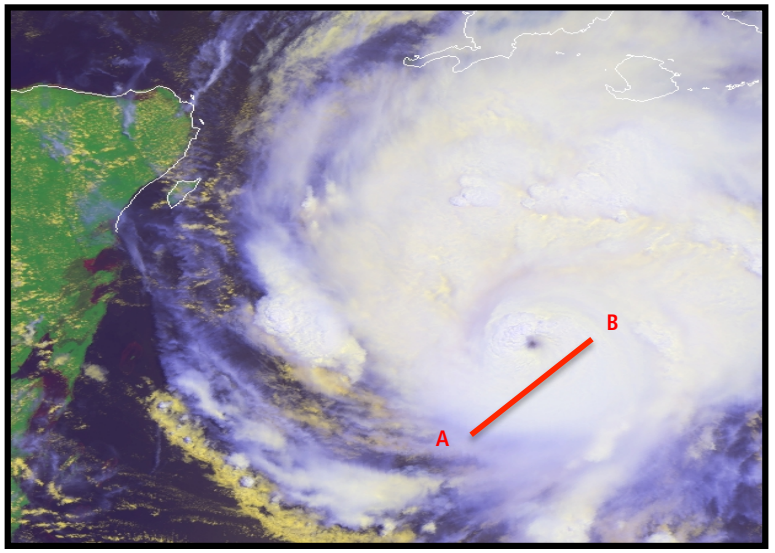


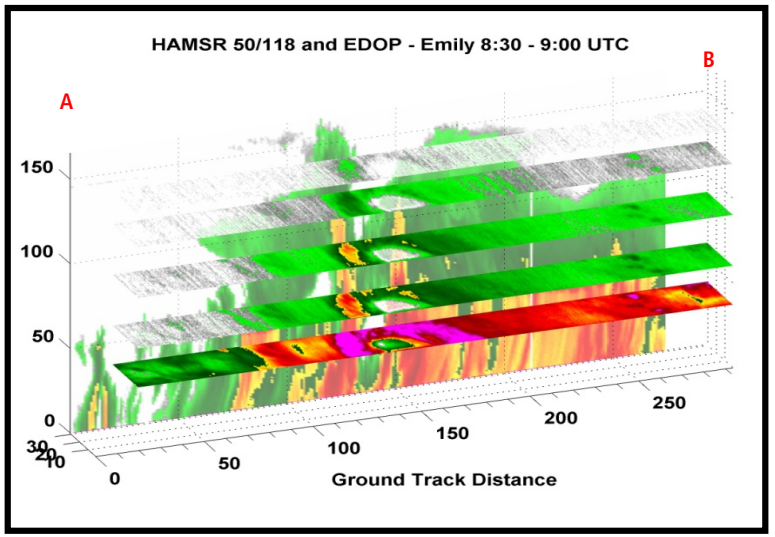
CHAISR: Top-level requirements

- Continuous operation >3days
- Temperature & humidity profiles
  - Swath width >40 km
  - Horizontal resolution >2 km
  - Vertical resolution 2~3 km
- Cloud top height & distribution
  - Swath width >20 km
  - Horizontal resolution <100 m
- Near-realtime data delivery & display



Typoon HaiKui on August 6, 2012 at 1857 UTC as it was moving toward China, which lasted for 8 days on 11 Aug (http://pmm.nasa.gov/mission-updates/trmm-news/typhoon-haikui-heading-toward-china)



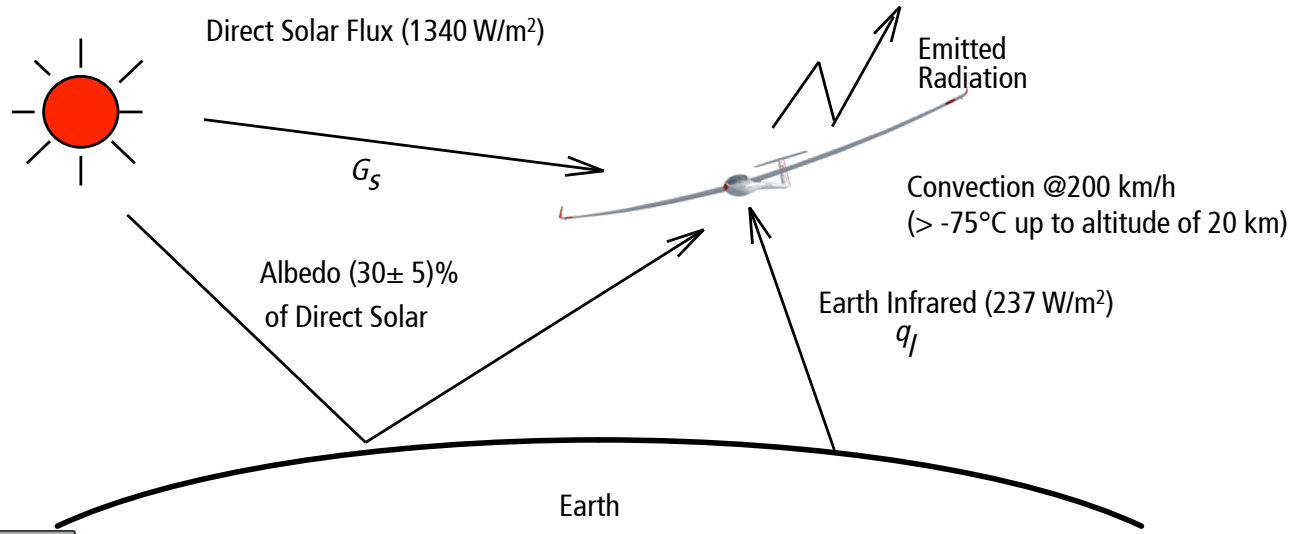


Hurricane Emily (17 July 2005). Courtesy NASA JPL.

CHAISR: Design constraints

- Mounted on front of UAV fuselage
- Attitude behavior of the platform
- Mass 4 kg
- Available power 50 W (24h)
- Pressure 50 mbar
- Temperature
  - For storage -75°C~+63°C
  - For operation -65°C~+43°C
  - Varying operational thermal environment

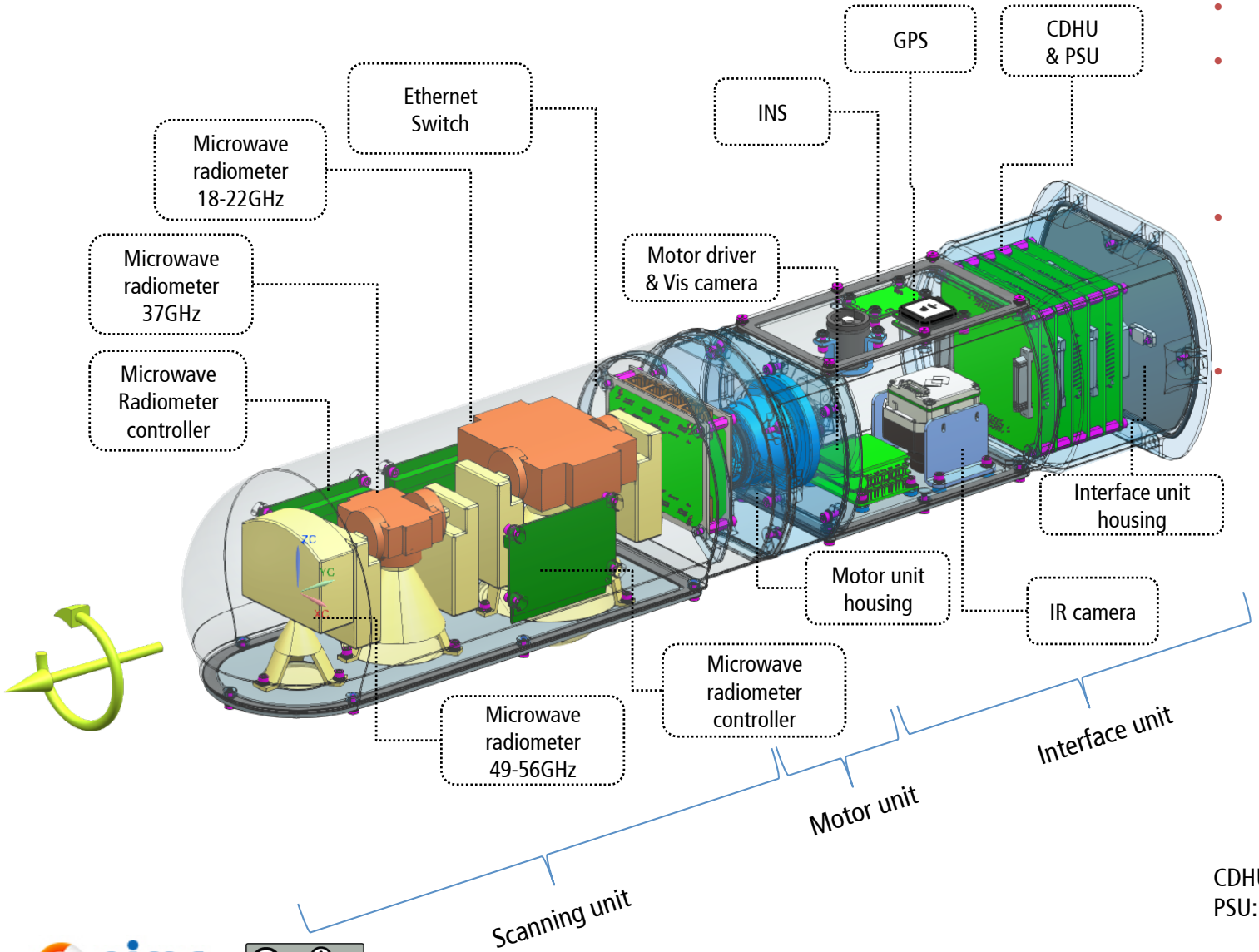
Category	Ground	Target altitude
Altitude	0km	20km
Temperature	-32~+43 ℃	>-75 ℃
Pressure	1013 hPa	50 hPa
Density	1.205 kg/m3	0.08816 kg/m3
Gravity	9.8 m/s2	9.733 m/s2
Solar radiation	1000 W/m2	1366 W/m2
Wind speed	Varying	Ave. : 6 m/s Max : 40~50 m/s
Flight speed	0~200 km/h	200 km/h



Meteorological sensors

Types	Sensor	Specifications	Notes
Remote sensors	**Radiometer**	Band #1, 2ch @ 22GHz Band #2, 2ch @ 37GHz Band #3, 7ch @ 50GHz	- Scan angle 0~55° - Cross-track width 22 km - Horizontal/Vertical resolution ~2 km / 2~3 km
	Visible camera	Spectral range 0.55 ~ 0.80 μm Channel no. ≥1 Sensor type CMOS or CCD Pixels ≥ 800 × 600 Dynamic range ≤ 14 bit Spatial resolution ≤ 100 m	
	IR camera	Spectral range 10 ~ 12 μm Channel no. ≥ 1 Sensor type Uncooled micro-bolometer Pixels ≥ 640 × 480 Dynamic range 14 bits Sensitivity ≤ 50 mK Spatial resolution ≤ 100 m	- Micro-bolometer - MI (Meteorological Imager) in KMA's COMS-1 Channel 1: 10.8 μm (Centre wavelength) Channel 2: 12 μm (Centre wavelength) - Detailed specification may change due to weight & power constraint
In situ sensors	**Thermometer**	Range -80℃ ~ 60℃ Resolution 0.01℃ Accuracy ±0.226℃	- Standard for meteorological sensors in high altitude (KMA Ref. 2012-1) - Standard for automatic weather station (KMA Ref. 2010-5)
	Humidity	Range 0 … 100 %RH Resolution 0.1% RH Accuracy ±1.7% RH	
	Pressure	Range 5~1050hPa Accuracy < ±1.0hPa Operational temp. -90~+60°C Resolution 0.1hPa	

Preliminary design Mk1



- **Dimension (Ø160.0 & 652.2 mm)**
- **Scanning unit :**
  - Microwave radiometer
  - Thermometer
  - Network hub
- **Motor unit :**
  - Motor
  - Slip ring
  - Bearing & Shaft
- **Interface unit :**
  - IR & Visible camera
  - GPS/IMU
  - Motor driver
  - Interface board
  - CDHU & PSU

CDHU: Command & Data Handling Unit
PSU: Power Supply Unit

Scanning Unit: Microwave Radiometer

- Weight & power constraints - Avoid onboard blackbody
- Pseudo correlation receiver
  - Continuous & simultaneous evaluation of a "scene" and "reference"
  - Maximizing integration time leads lower instrument noise
  - Used in radio astronomy
    (Tuiri, 1964; Mennella et al., 2003; Harris, 2005)
- Monolithic Microwave Integrated Circuits (MMICs)
  - x4 types of custom MMICs per radiometer
  - Hybrid, Phase shifter, Detectors, and LNA

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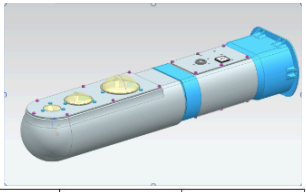
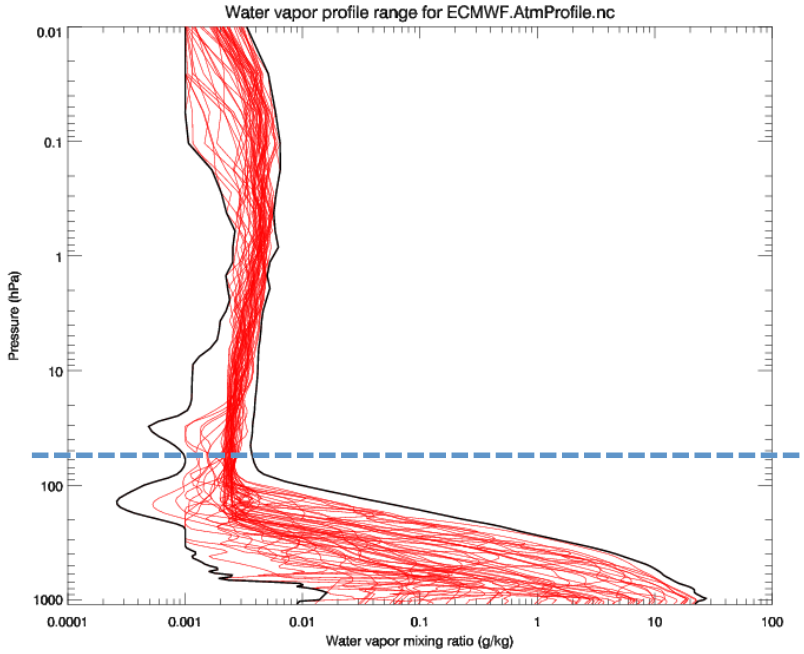
RF and feed horn

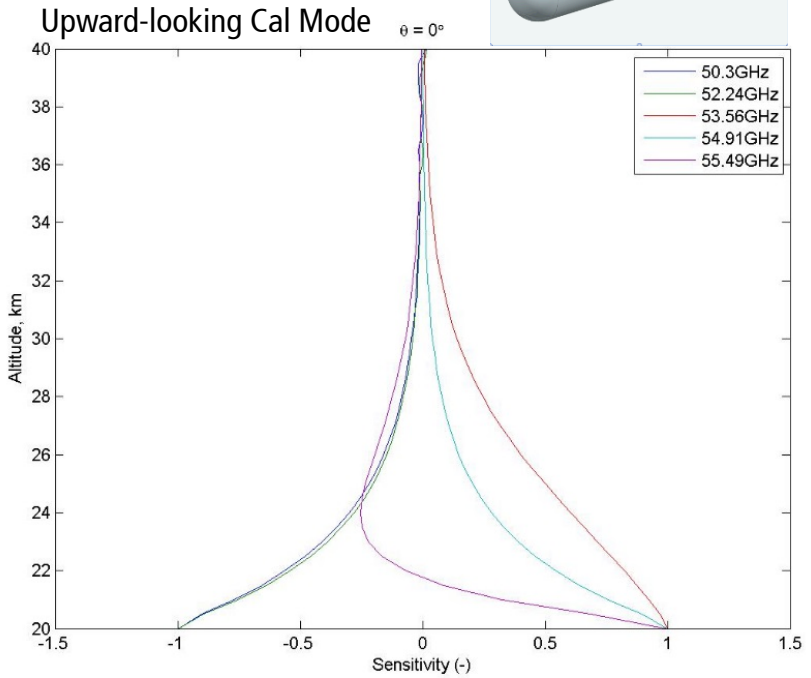
#	Frequency (GHz), (bandwidth MHz)	Polari-sation	No of channels	Beam width	Footprint (km)	Satellite instrument	Weight (Antenna, Receiver)	Power
1	18.7 (750) 22.235 (400)	V,H	4	16	10.29 x 18.01	WindSat (AMSR2, GMI, SSM/I)	352.8 g, 240.0 g	4.8 W
2	37 (1600) 40 (1600)	V,H	4	11	6.88 x 12.06	SSMIS (SSM/I, GMI, AMSR2)	133.6 g, 170.0 g	5.2 W
3	50.3 (2000) 52.24 (1280) 53.56 (960) 54.91 (340) 55.49 (340)	V	5	11	6.88 x 12.06	SSMIS (ATMS, AMSU-A, Lipton 2003)	65.2 g, 133.0 g Mass: 1,094.6 g	2.8 W Power: 12.8 W

Scanning Unit: Radiometer calibration

- Weight & power constraints - Avoid onboard blackbody
- Pseudo correlation receiver
- Upward-looking scan for sky temperature
  - Assuming atmosphere above flight altitude is comparably stable
  - Water vapour above flight altitude (50 hPa) is <1%
  - Radiometer tends to be less sensitive above flight altitude (Band #3)

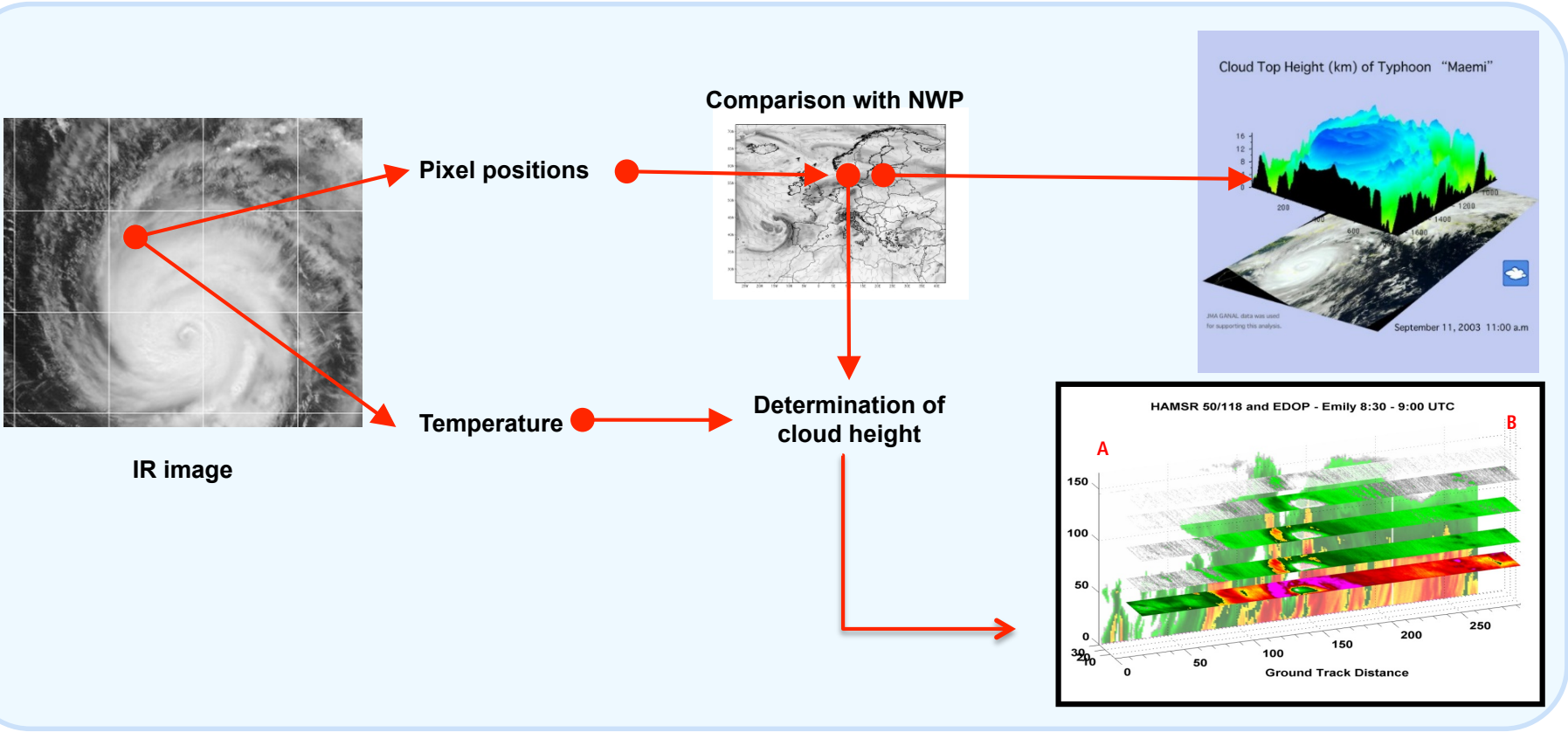




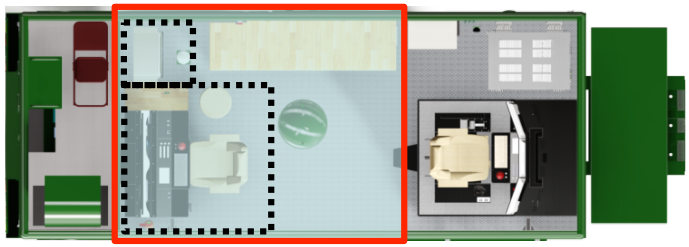


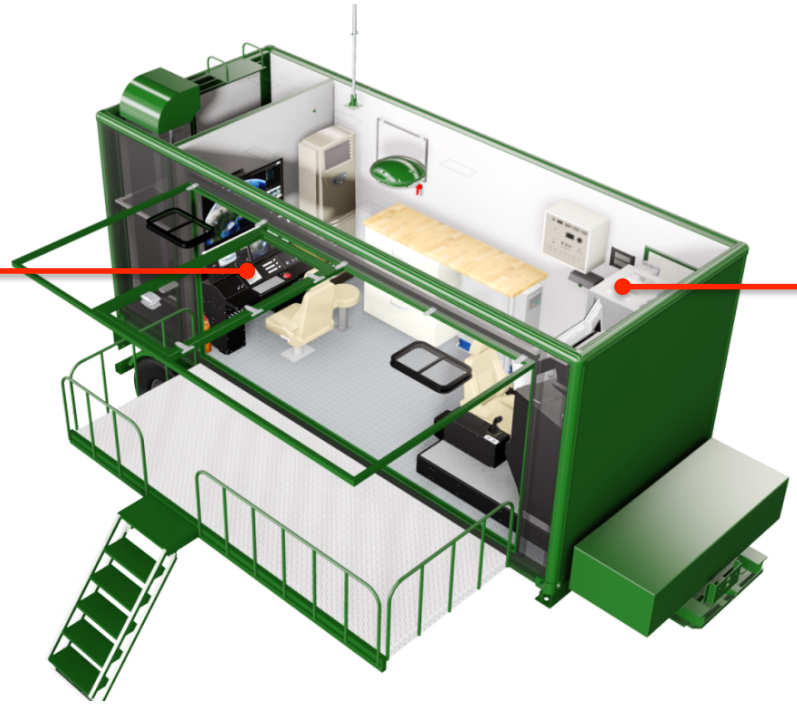
Interface Unit: IR camera

- Monitoring spatial distribution of clouds
- Acquiring cloud top height
- Additional information for retrieval of vertical profiles of temperature & humidity from microwave radiometers



Conceptual design of ground segment





Payload control unit

Observation screen

Payload control screen

Operator seat

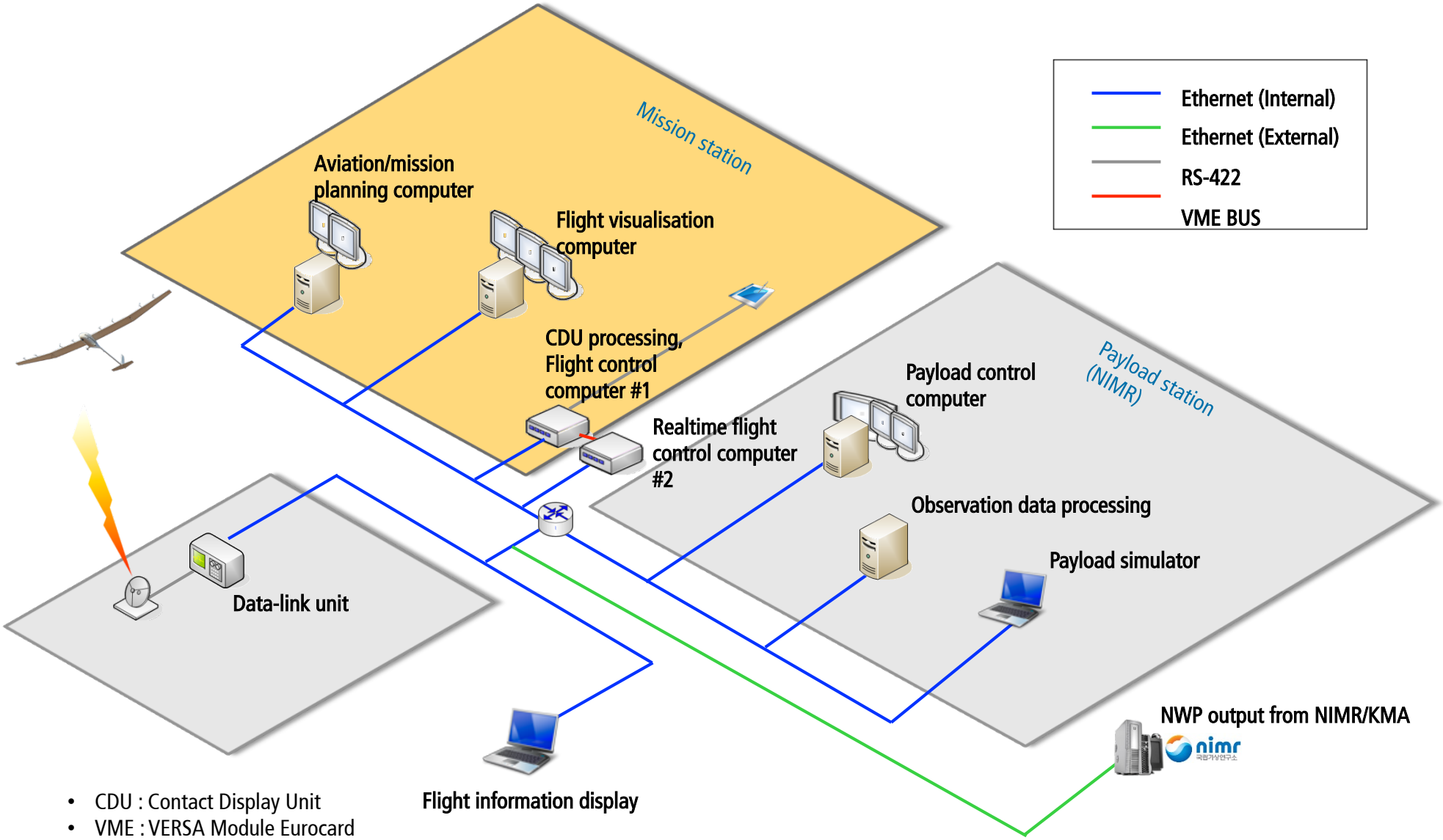
Assistant operator seat

Payload control computer

Observation visualisation computer

Payload control computer unit

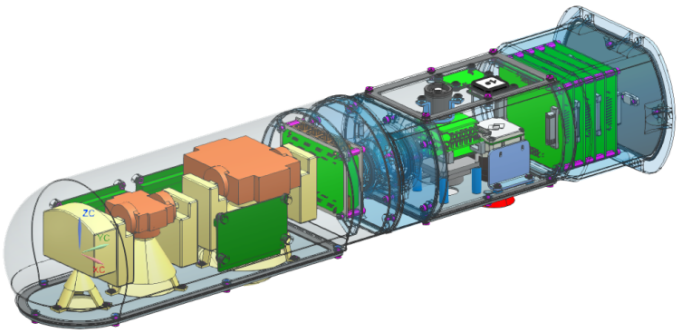
Conceptual design of ground segment

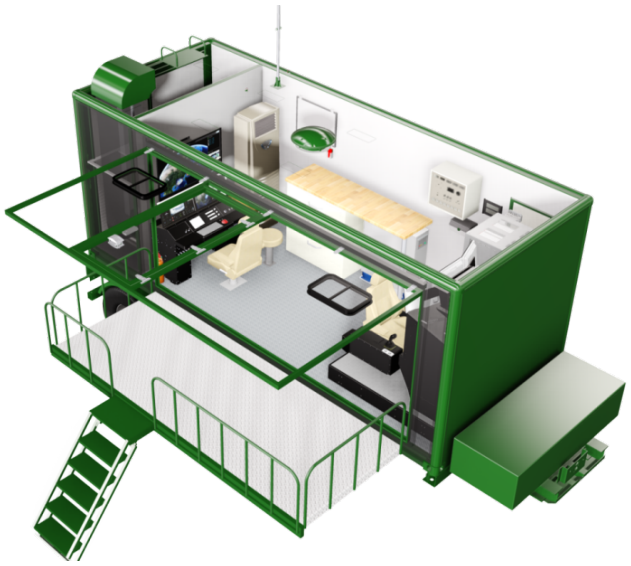


- CDU : Contact Display Unit
- VME : VERSA Module Eurocard

Conclusions

- Light-weight compact meteorological remote sensing payload for HALE UAV(s)
- Objectives:
  - Meteorological observation (Temperature & humidity sounding & clouds)
  - Unmanned air planning for UAV operations
- Decision criteria for final design
  - Extreme operational environment and conditions (low pressure, thermal cycle, etc)
  - Mass and power constraints
- Future milestones
  - Critical Design Review (CDR): January 2016
  - Test Readiness Review (TRR): December 2016
  - Flight Readiness Review (FRR): May 2017





Q&A

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E. renochoi@korea.kr

Austrian skydiver Felix Baumgartner is well on the way to setting a world record for the highest free-fall jump on 15 March 2012. Later, broke the record in July 2012 (97,063 feet / 29,584 meters)

Altitude reached: 71,615.2 ft / 21,828.3 meters
Parachute opened at: 8,210.6 ft / 2,502.6 meters
Freefall time: 3 minutes and 40 seconds
The fastest ascent rate of the capsule: 1,200 feet per minute (estimate)
Speed reached in freefall: 364.69 mph / 586.92 km per hour

Photo credit: Jay Nemeth / Red Bull Stratos / AP
http://http://www.redbullstratos.com/