



NASA Flight Opportunities

Advancing Small Spacecraft Technologies with Suborbital Flight Tests

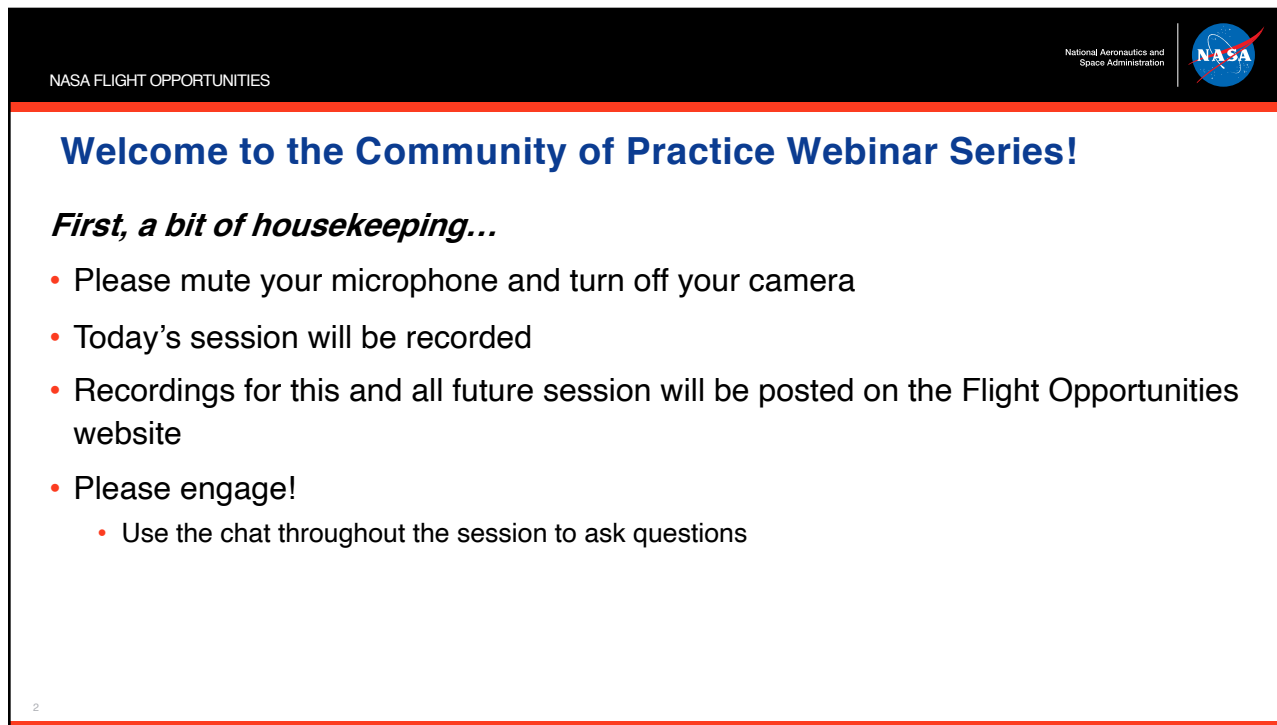
Anh Nguyen, Ph.D., NASA's Ames Research Center
Mary Palmer, Raven Aerostar
Paul De León, Flight Opportunities

Community of Practice Webinar Series – September 8, 2021

Session will start at 10 a.m. PT – Please mute your microphone and turn off your camera

www.nasa.gov

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Welcome to the Community of Practice Webinar Series!


First, a bit of housekeeping...

- Please mute your microphone and turn off your camera
- Today's session will be recorded
- Recordings for this and all future session will be posted on the Flight Opportunities website
- Please engage!
 - Use the chat throughout the session to ask questions

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NASA FLIGHT OPPORTUNITIES

National Aeronautics and Space Administration



Flight Opportunities Mission

The Flight Opportunities program facilitates **rapid demonstration** of promising technologies for space exploration, discovery, and the expansion of space commerce through **suborbital testing with industry flight providers**.




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Now Open - NASA TechRise Student Challenge

- For teams of sixth to 12th-grade students to design, build, and launch experiments on suborbital rockets and balloon flights during the upcoming 2021/2022 school year
- Entries due **November 3**
- For more info on the challenge, proposal requirements, and the upcoming virtual field trip: <https://www.futureengineers.org/nasatechrise>




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Join us for future Community of Practice webinars!

Interactive Exchange:

Come ask questions and share your experience with a panel of veteran Flight Opportunities PIs

 October 6 at 10–11:30 a.m. PST

Future webinars


- Webinars are held 1st Wednesday of each month at 10 a.m. PT
- Topics will be announced in the Flight Opportunities newsletter and website
- Session recordings will be posted on the Flight Opportunities website
- Let us know session topics you would like to see covered

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Today's Speakers



Anh Nguyen, Ph.D.
Aerospace Engineer
NASA Ames Research Center



Mary Palmer
Program Manager
Raven Aerostar



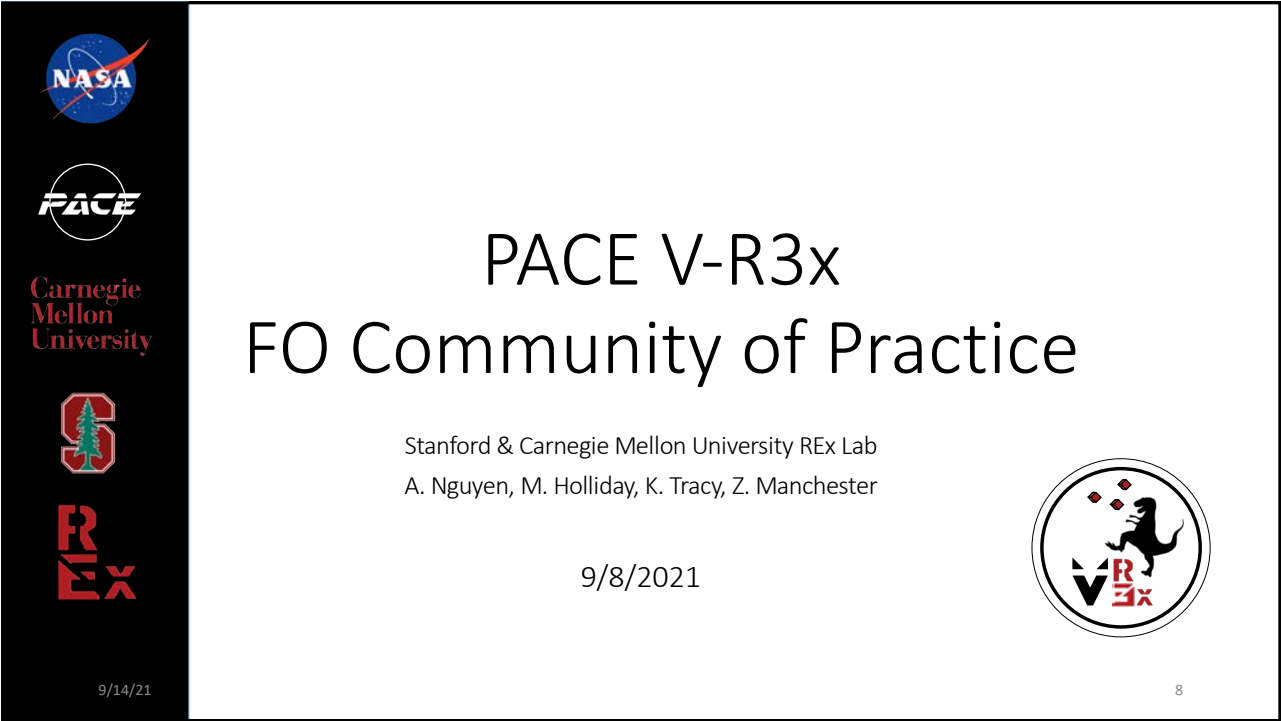
Paul De León
Campaign Manager
Flight Opportunities

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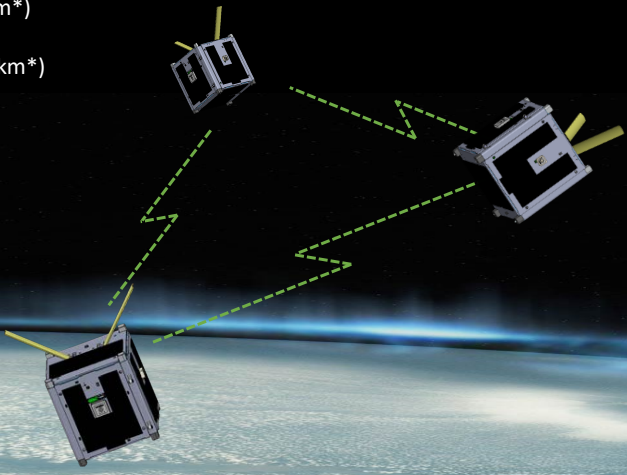
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Tech Demo Activities




- **S-band ranging** <1 m precision (distances >500 km*)
- **Hi-speed S-band cross-link demo** (distances >10 km*)
- **Coordinated radiation measurements**
- **Relative swarm topology recovery**





*link budget dependent

9/14/21

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Project Summary




```
graph TD; A["V-R3x ATP  
1/6/2020"] --> B["V-R3x Orbital Launch  
1/24/2021"]; B --> C["V-R3x-S Suborbital Flight Campaign  
3/11/2021"]
```


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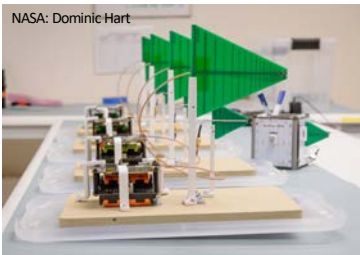
Orbital vs Suborbital Comparison



Description	V-R3x Orbital	V-R3x-S Suborbital
# Units	3	5 (1 Balloon + 4 Ground)
Launch Date	1/24/2021	3/11/2021
Target Altitude	525 km, SSO	30.48 km (100,000 ft)
Mission Ops Duration	6 mo.	2 hrs at float (5 hrs total)
Requirements	<ul style="list-style-type: none">S-band High Precision RangingS-band High Data Rate Cross-linkRelative Topology RecoveryDistributed radiation sensor collection	<ul style="list-style-type: none">S-band High Precision RangingS-band High Data Rate Cross-link
Networking	Mesh Network w/ 3 nodes	Mesh Network w/ 5 nodes



V-R3x Orbital




NASA: Dominic Hart

V-R3x Suborbital

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V-R3x Build


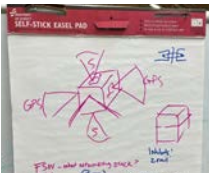
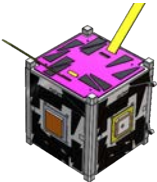


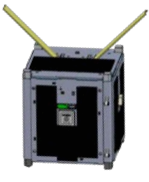
Image Credits : NASA




Brainstorm
12/03/2019




Project Proposal
12/16/2019




PDR/CDR
05/18/2020




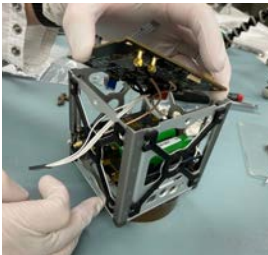

EDU
08/31/2020



FM 09/27/2020




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V-R3x Ridge Testing


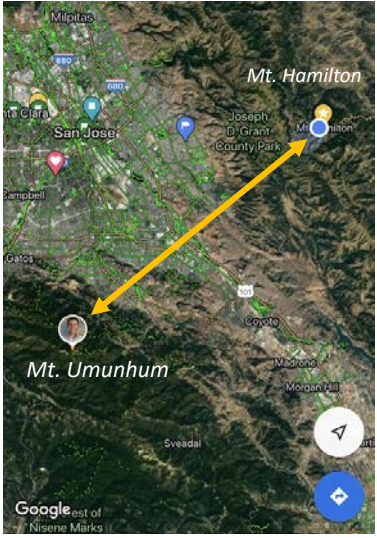



Image Credits : NASA




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- UHF link closed
- S-band ranging & link didn't close
 - Likely due to valley noise

View from Mt. Hamilton



V-R3x #2
@ Mt. Umunhum

V-R3x #1

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First Spacecraft Packets Received





V-R3x Mobile Ground Station



GS Setup



GS Equipment



First V-R3x Decoded Packets!

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Downlink RX UHF

Zac Manchester
Carnegie Mellon University

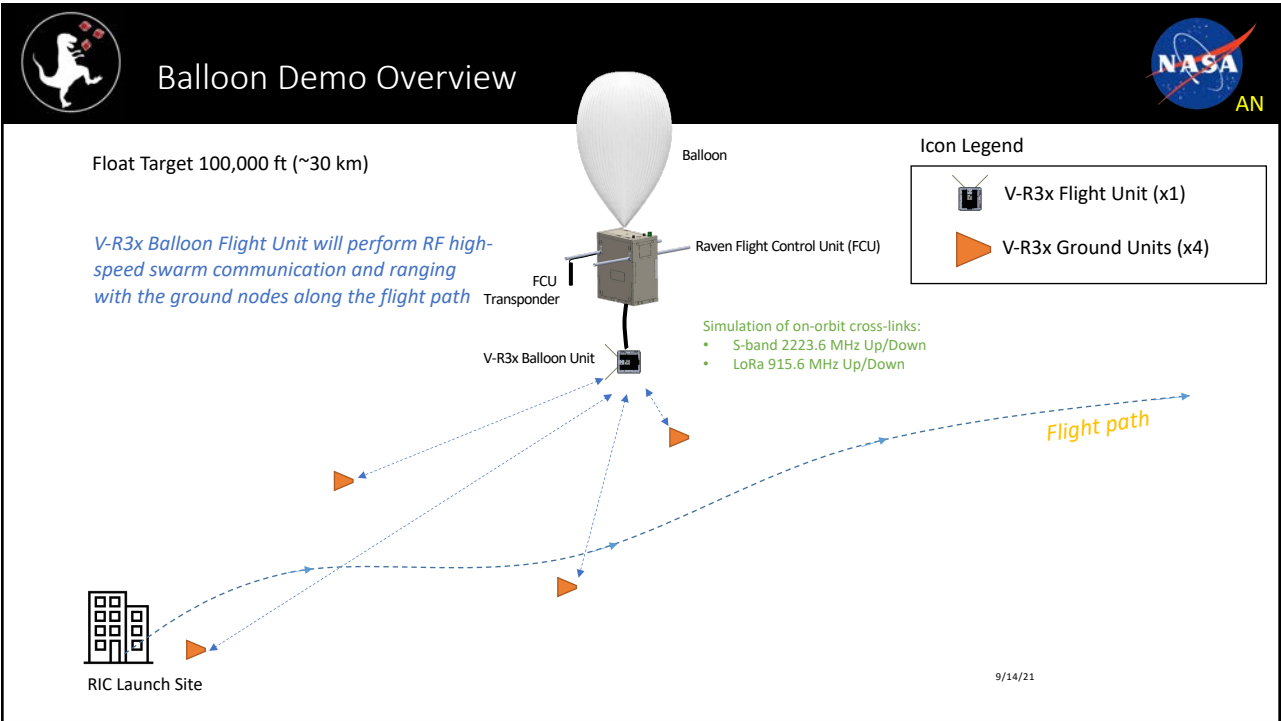
Max Holliday
Stanford

Anh Nguyen
NASA ARC

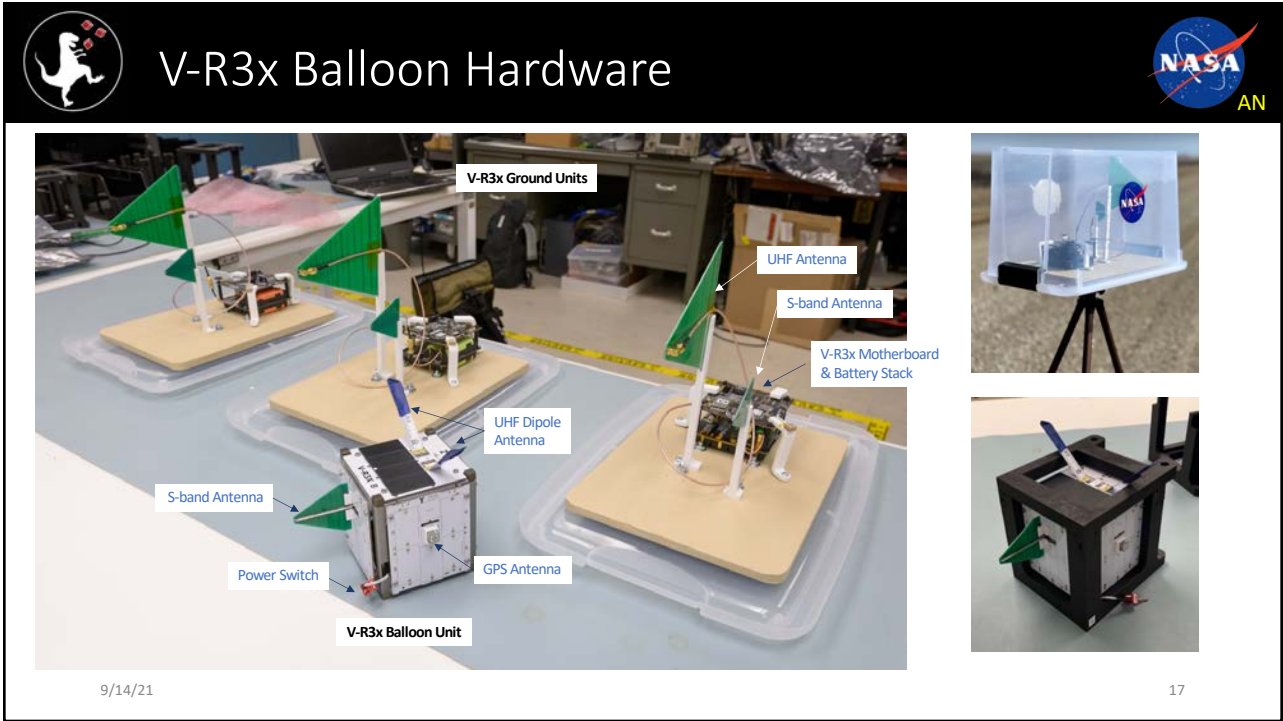
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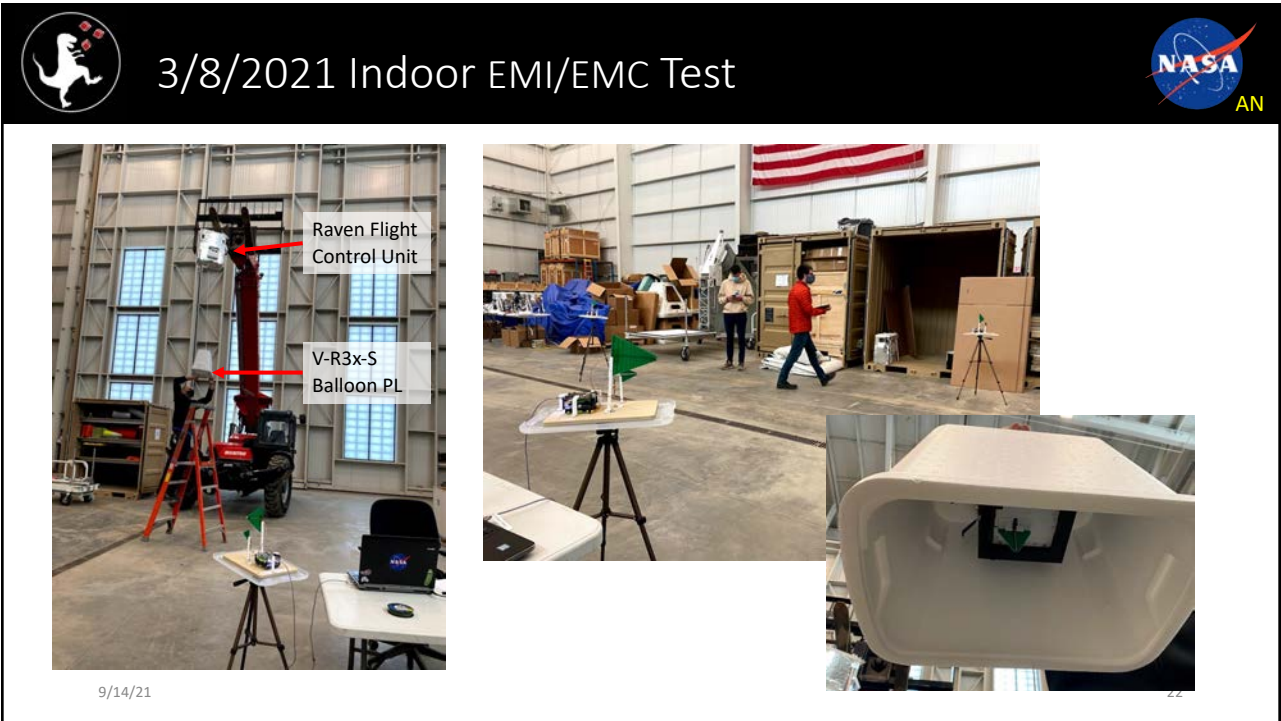


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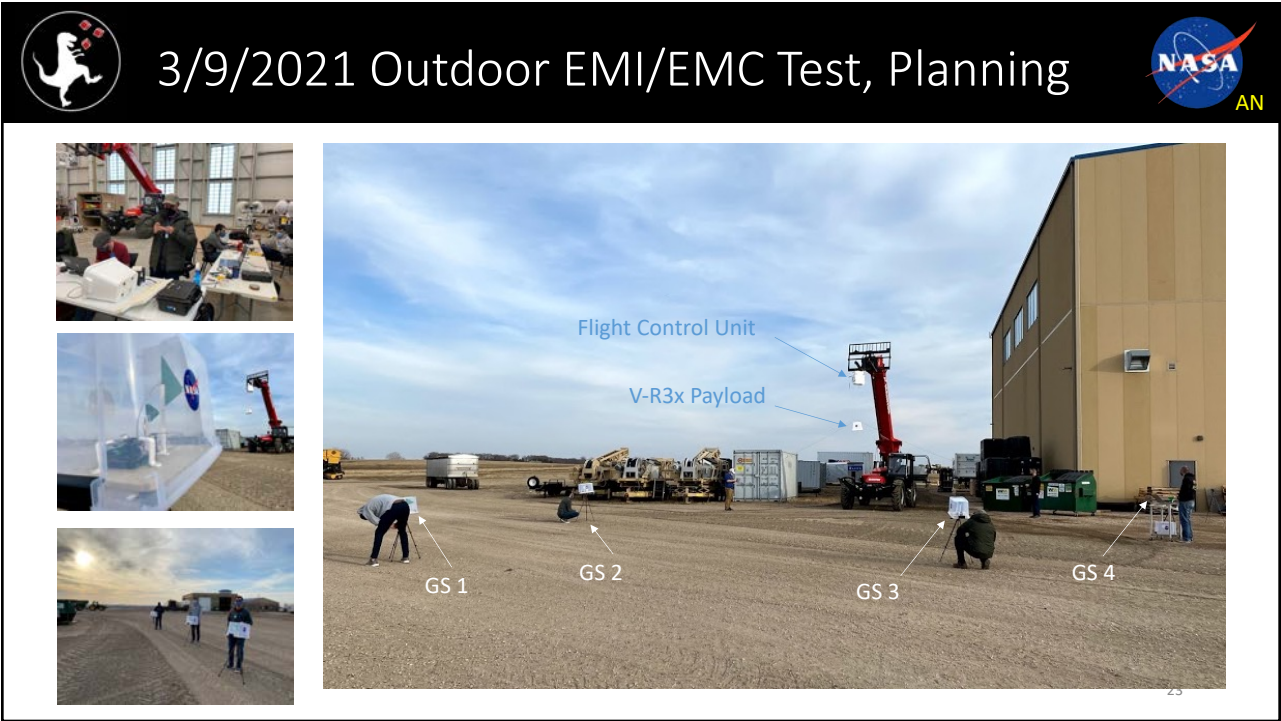




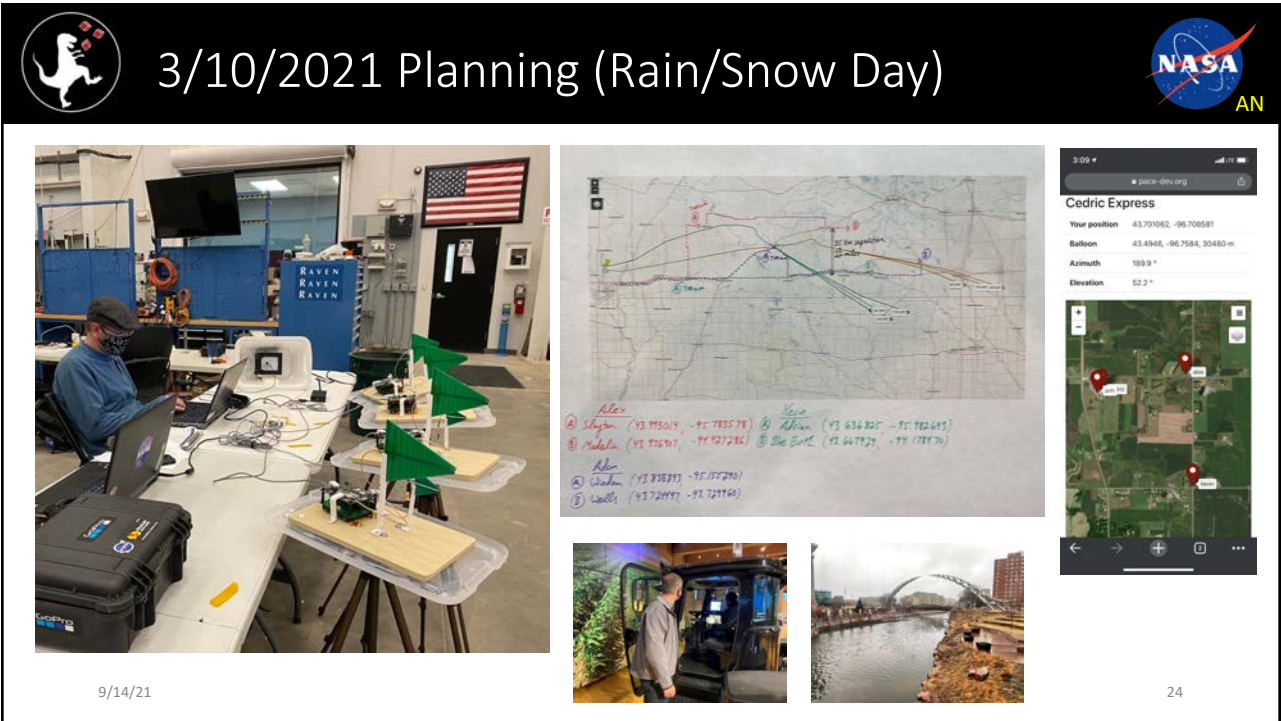
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Experiment Summary




- Balloon unit successfully networked with each of the ground units over a duration of 5.2 hrs
- Successful mesh networking
- Successful high-speed data transfer S-band and UHF
- No S-band ranging data collected ☹
 - Frequency offsets (EFE's) collected for all links
 - Ranges not calculated
 - Successful GPS lock maintained throughout the duration of the flight


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Ranging Anomaly – Testing



- Fixed the IRQ routine to check for bit-by-bit changes w/ documentation
- Selected new parameters to optimize timing and link budget and pick the SF/bandwidth for this scenario
- Range test 4/4 – All nominal
- Ridge testing 4/9 – Same anomaly observed
- Implemented firmware fixes
- Ridge testing w/ successful ranging 4/30




Units	SF	Bandwidth	Ranging Distance	Ranging Precision
Orbit	10	1600 kHz	Short	Best
Balloon	10	400 KHz	Long	Worst
Ridge Testing	10	800 KHz	Medium	Medium




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Suborbital Lessons Learned




Lessons Learned

- Suborbital demonstration before orbital demonstration would have been useful to address bugs
- GPS, UHF, and S-band Link budget better than expected for terrestrial demo
- High speed comm verified hardware limits
- Expected temperatures very cold
- Gather more data if possible of env. (temp, acceleration, etc.)
- Always get TSA paperwork; carry-on hardware does not fit in overhead cabins of older regional planes
- Check hardware end-of-day; go through debug exercise with everyone during campaign
- Stay on top of your STA
 - Submit with plenty of margin
- Raven has a lot of knowledge, materials, and expertise – lean on them
 - Mechanical, Thermal, and Flight patterns
 - Environment at Raven dustier/drier than expected
- Achievements:
 - Demo'd meshed networking and debugged ranging
 - Valuable lessons learned for future comm mesh networking suborbital experiments


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PACE Global Lessons Learned



- Suborbital demonstration provides critical data and lessons learned to increase mission success for orbital demonstrations
- Ability to rapidly demonstrate this technology could not be done without University partners and PyCubed architecture
- Lessons learned from rapid V-R3x demo can enable future rapid follow-on missions (<12 mo.)
- COVID-19 impacts severely compressed schedule
- RFA is always an issue
- V-R3x provided many lessons learned and valuable experiences for shaping of PACE series of mission on how to technically and logistically bridge FO to SST opportunities

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Balloon Systems	Thunderhead SPB	Cyclone ZPB
Balloon Volume	64,000 ft ³	Mission specific
System Duration	30+ days	1-2 days
Maximum Altitude	50-75 kft	Up to 130,000 ft
Maneuver Range	≤20,000 ft	Mission specific
User Payload Weight	≤125 lbs	≤125lbs standard (higher weights possible w/ custom gondola)

Unrestricted
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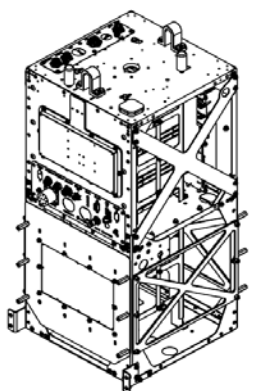
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Payload Services	
User Payload Power:	Up to 2400Wh; 4 switchable +28V rails (600W peak)
LOS Communications	S-Band – 1-40Mbps (range dependent)
BLOS Communications	Iridium – intermittent, short burst data
Launch Capability	Land/Marine
Payload Data Services	Real-time GPS/INS Data, High Rate C2,
Mission Planning	FAA Coordination, Range Safety, Flight Modeling



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Thank you!

Flight Opportunities website:
<http://nasa.gov/flightopportunities>

Contact us:
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