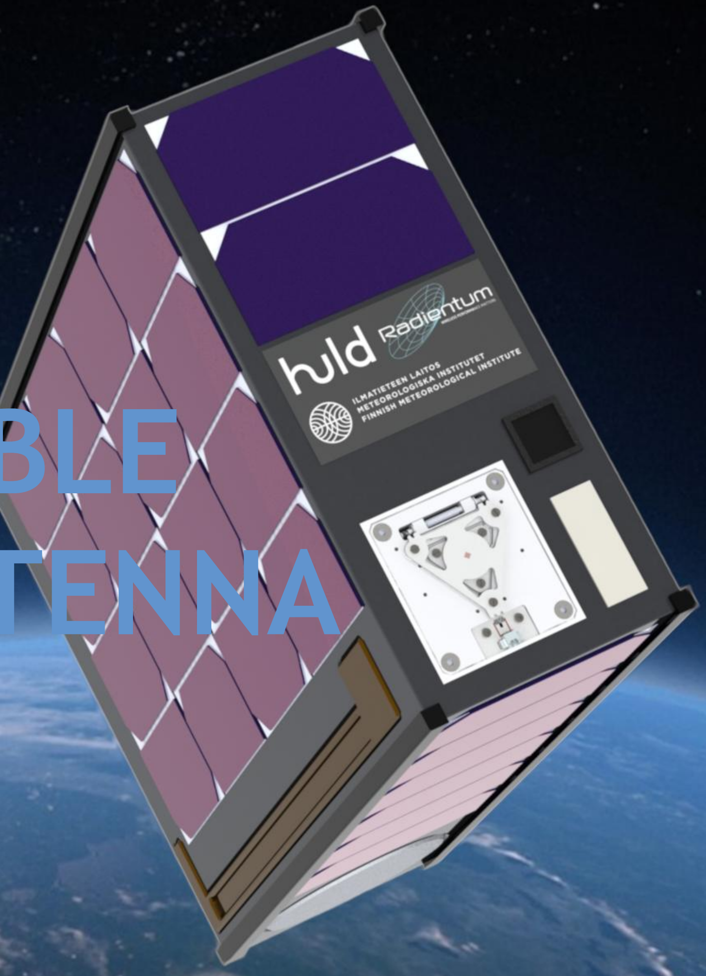
NAVISP-EL1-083: DEPLOYABLE SATELLITE NAVIGATION ANTENNA WEBINAR PRESENTATION



19/11/2025

Customer: ESA
Project: NAVISP-EL1-083: DEPLOYABLE SATELLITE NAVIGATION ANTENNA
Document ID: NAVISP1-FPH-HULD-083-00042
Document version: 1.0
Author: Jaakko Kaartinen, Heli Saunamäki, Juho Veteläinen, Riku Kormilainen, Mikko Kärnä Leino, Harri Haukka, Antti Kestilä

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Speakers of today

Juho Veteläinen
Project Manager, **Huld**
juho.vetelainen@huld.io

Jaakko Kaartinen
Senior Mechanical Designer, **Huld**
jaakko.kaartinen@huld.io

Mikko Kärnä Leino
Senior Antenna Engineer &
Project Manager, **Radientum**
mikko.leino@radientum.fi

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Source: https://navisp.esa.int/opportunity/details/106/show

Agenda

- Introduction (*J.Veteläinen*)
- Project summary (*J.Veteläinen*)
- Project results and achievements (*J.Kaartinen & M.Kärnä Leino*)
- Next steps (*J.Veteläinen*)
- Q/A

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Radientum
WIRELESS PERFORMANCE MATTERS

huld

Introduction

huld

Project motivation

"The utilization of small and nano satellites in LEO orbit, and the need for even better navigation accuracy, suggests the study of new frequency band antennas, that can be stowed at launch."[1]

[1] ESA-TDE-TECEFA-SOW-2023-002729

Project motivation

- Usage of Ka-band antennas is very limited, only approx. 2% of small satellite missions during the years 2003 to 2022
- Potential for Ka-band area utilization in the future due its better navigation accuracy as well as small size and minimal payload
- Increasing number of satellites in Low Earth Orbit creates need for precise navigation

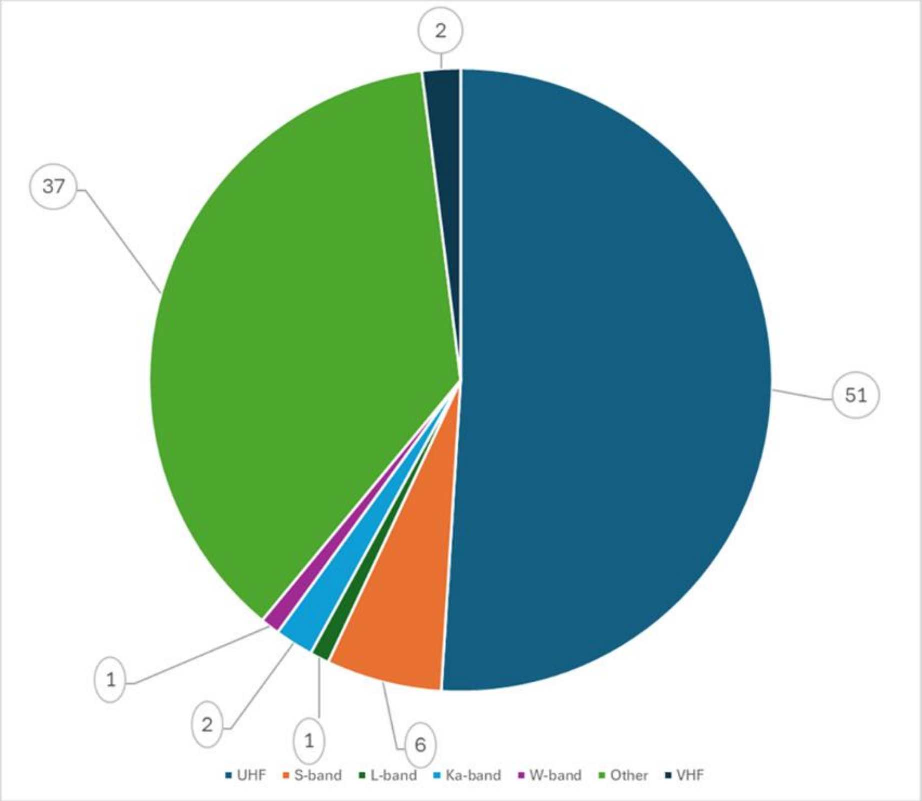


Image 1. The division of the small satellite platform mission antenna frequencies reviewed by the Liu et.al.

Liu, S.; Theoharis, P.I.; Raad, R.; Tubbal, F.; Theoharis, A.; Iranmanesh, S.; Abulgasem, S.; Khan, M.U.A.; Matekovits, L. A Survey on CubeSat Missions and Their Antenna Designs. *Electronics* 2022, *11*, 2021. https://doi.org/10.3390/electronics11132021

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Project summary

Project consortium

huld

Prime

- European technology design house with 500 experienced design professionals, part of Gofore group
- Core space competence in real-time software for space applications proven in +150 ESA projects since 1989
- Evolving mechanical design capability for space domain, including additive manufacturing expertise
- **Responsible of project management and mechanical & structural design of the product**

Radientum

Sub-contractor

- Radientum, founded by ex-Nokia/Microsoft experts, is a growing antenna design startup from Finland
- Multiple OTA chambers, EMC debugging, RF shielding, and dielectric material testing systems
- With 700+ projects completed, Radientum designs antennas from MHz to 100+ GHz, including wearables and automotive radar applications
- **Responsible of RF design and antenna testing coordination**

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Sub-contractor

- FMI is Finland's largest space research organization, with 120 staff and decades of experience in space instruments, Earth observation, and planetary missions since 1985
- FMI has delivered over 50 instruments for missions like Cassini, Rosetta, Phoenix, and Perseverance, and contributed to CubeSat projects like Aalto-1 and Suomi-100
- FMI leads ESA studies such as MiniPINS, DragLiner, and HighPeek, developing and testing satellite components to reach TRL 4-5
- **Responsible of mission planning, and area expertise providing for the project**

Image 2. Project consortium

Project schedule

WP1			WP2			WP3				WP4						WP5	
Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sept-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sept-25
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18
WP Leader: FMI			**WP Leader: Radientum**			**WP Leader: Huld**				**WP Leader: Huld**						**WP Leader: Huld**	
State-of-the-art Review and Mission Concepts Consolidation																	
			Trade-off Analysis of Preliminary Antenna Design														
						Antenna Detailed Design											
										Breadboard Manufacture and Test							
																Exploitation of Innovation	
End event: **Requirements Review**			End event: **Preliminary Design Review**			End event: **Critical Design Review**				End event: **Test Review Board**						End event: **Final Review**	

Image 3. Simplified project Gantt chart

Project WBS

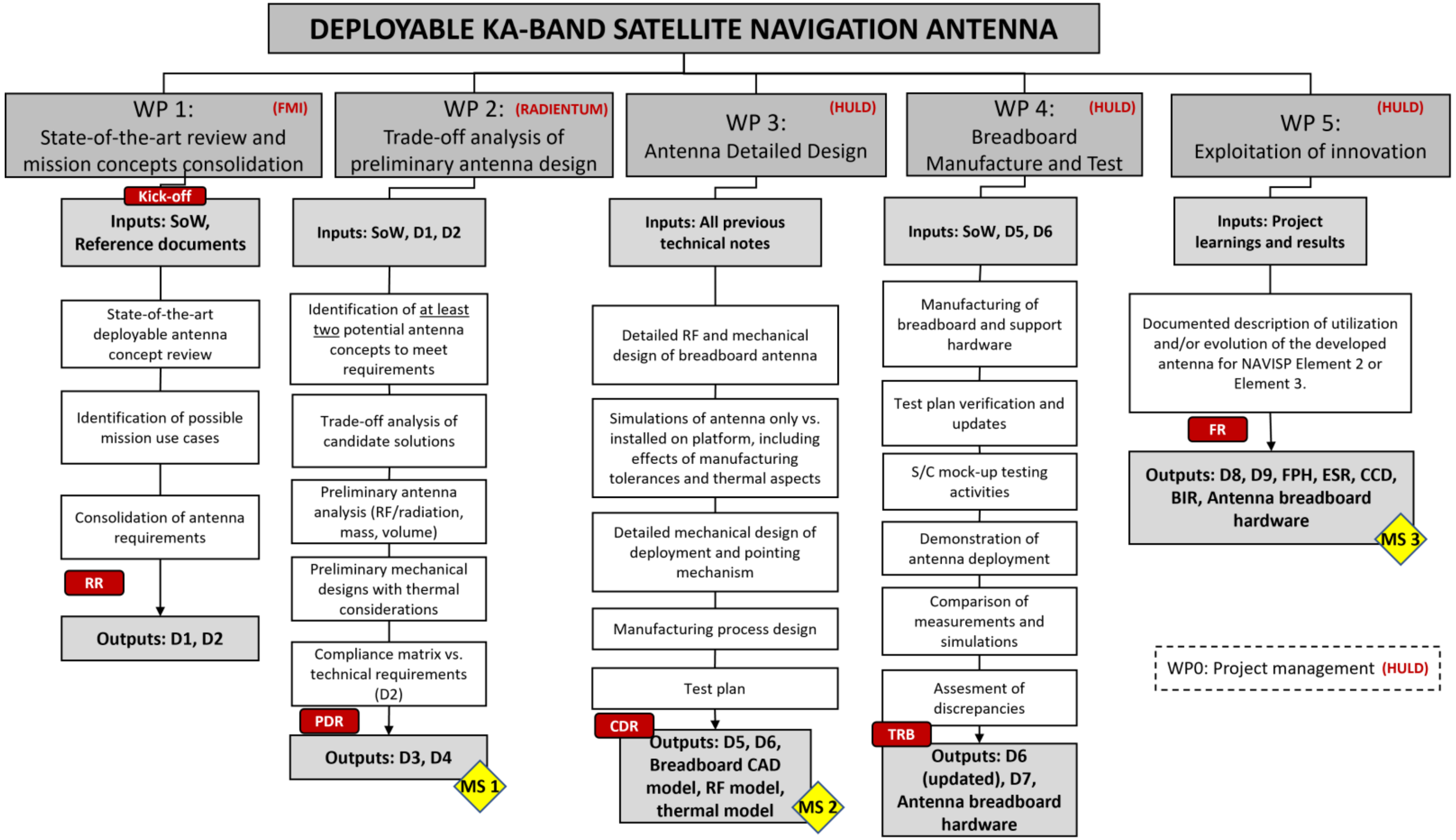


Image 4. Work Breakdown Structure

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Radientum
WIRELESS PERFORMANCE MATTERS

huld

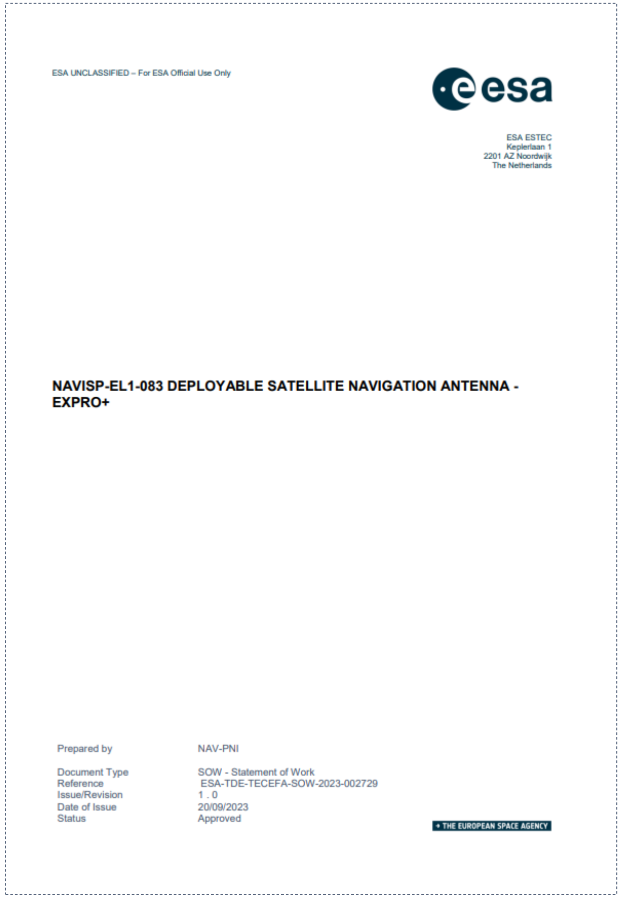
Main product requirements

Mechanical requirements:

- MECH-01: The stowed antenna shall be compatible with a ‘n x 10xm’ Cubesat
- MECH-02: The mass of the antenna shall be minimized to be suitable for a ‘n x 10xm’ Cubesat
- MECH-03: The temperature range the feed shall be operational over shall be -120° - +120°C

Electrical requirements:

- ELEC-01: The antenna shall be dual circularly polarized
- ELEC-02: The antenna shall operate in Ka-band
- ELEC-03: The –3dB beamwidth of the antenna shall be ± 30 degrees


ESA UNCLASSIFIED – For ESA Official Use Only

esa

ESA ESTEC
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands

NAVISP-EL1-083 DEPLOYABLE SATELLITE NAVIGATION ANTENNA - EXPRO+

Prepared by	NAV-PNI
Document Type	SOW - Statement of Work
Reference	ESA-TDE-TECEFA-SOW-2023-002729
Issue/Revision	1 . 0
Date of Issue	20/09/2023
Status	Approved

→ THE EUROPEAN SPACE AGENCY

Image 5. Statement of Work

[1] ESA-TDE-TECEFA-SOW-2023-002729

Project results and achievements

huld

WP1 - State-of-the-art review and mission concepts consolidation

WP1			WP2			WP3				WP4						WP5	
Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sept-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sept-25
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18

Recap of the work purpose and content

- Review and analyze current Ka-band deployable antenna concepts and potential use cases for small satellite navigation applications.
- Define technical requirements, propose the most viable concepts, and compile a comprehensive verification plan for further development.

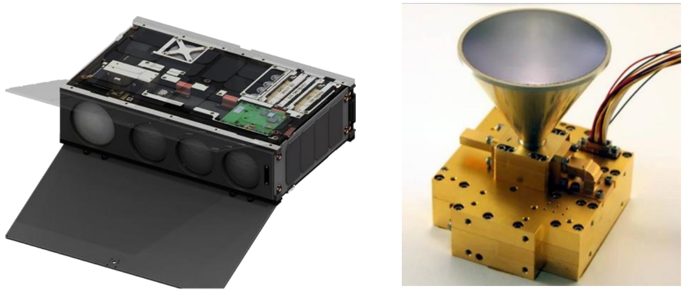


Image 6: Landmapper-BC / Corvus-BC satellite on the left and Ka-band unit on the right. Images: Astro Digital.

WP1 - State-of-the-art and mission concepts review

- **First step:** Review of the existing and space used deployable antennas and antennas in Ka-band range
- **Second step:** Spacecraft navigation and used antennas review
- **Third step:** Potential design approaches

Radar type	Number of antenna feeds	Antenna complexity	Reliability	Range	Accuracy	Beam rotation with min. number of antennas	Speed of tracking
Conical	1	Low complexity needed. The cross-sectional pattern should be omnidirectional	Environment and nearby clutter affects accuracy	Range depends on several factors	High accuracy with proper design	Mechanical rotation of antenna around axis required	Limited by antenna rotation and several pulses required.
Beam switching	4	Several different beams need to be produced.	No data available	Range depends on several factors	High accuracy with proper design	No mechanical rotation required.	Several pulses required.
Monopulse	2 or 4	Most demands on radar post-processing and antennas	Less prone to the effects of environment	Range depends on several factors	Highest accuracy with proper design	Mechanical rotation of antenna around axis required if two antennas are used.	One pulse required.

Image 7. Comparison between different radar types

- Review matrix and first iteration of the potential design approaches
- Identified promising antenna design approaches
  - Feeding arrangement
  - Radiation arrangement
  - Beam guiding arrangement
- Space environment effects on antennas
  - Radiation
  - Material outgassing
  - Temperature variations
  - Multipaction breakdown

Criteria and short description	Stacked patches	Waveguide horn	Dielectric lens	Parabolic mesh reflector	Folded panel reflect array	*Optical [1]*
Gain (RHCP / LHCP)	Mechanical protection of the antenna adds gain	Gain can be adjusted with horn dimensions	Dielectric lens enhances gain	Reflector size and feed antenna adjust the gain	Array gain is mostly dictated by its aperture size (i.e. number of elements)	*N/A*
Antenna sensitivity to mechanical structures	Position accuracy of the patches critical	Gain is stable, phase center to be observed	Lens shaping, position and orientation critical	Surface accuracy of reflector is critical	Sensitive to the elements locations	*Lens shaping, position and orientation critical*
Antenna bandwidth	Stable response over required bandwidth	Stable response over required bandwidth	Stable response over required bandwidth	Can have wide enough band.	Can have over 100 MHz bandwidth	*N/A*
Antenna beamwidth	Widest axial ratio beamwidth	Smallest phase shift within a 120° observed beamwidth	Performance at beam edges is critical to lens design and tolerances	Very narrow, about 1.2°, requires very careful control over its position	Elements close to the center narrow beamwidth, elements close to the edge wider beamwidth	*N/A*
Antenna phase stability over the beam	Stable. Thickness of dielectrics may affect azimuth vs. Beam edge difference.	Stable	Critical from the beam edges	N/A	S-shaped curve of an element phase-change versus element-change.	*N/A*
Antenna axial ration in main cut planes vs. Targeted beamwidths	1 dB axial ratio over the specified beamwidth	At the limit of 3 dB axial ratio	7 dB axial ratio at the beam edges	N/A	N/A	*N/A*
Antenna scalability to higher gains in possible future evolutions	Scalable with patch count. Medium complexity.	Scalable with horn size. Low complexity.	Scalable with lens design. High complexity / not shrinkable.	Surface accuracy limits scalability to higher frequencies.	High complexity due to limited surface area available	*Optical system scalable, increases the mass and volume greatly*
Mechanical device(s) complexity	Med.	Low	High	High	Med.	*Med.*
Overall system complexity	Med.	Low	Med.	Med.	Med.	*High*
Overall system size	Low	Low	Med.	Med. Suitable 6U min.	High	*Med.*
Overall system mass	Low	Low	Med.	Med.	High	*High*
Manufacturing adaptability	Med.	Low	Med.	Low	Low	*Low*
Manufacturing complexity	Med.	Low	Med.	Med.	Med.	*High*
Technological and economic benefits	Small when packed	Small when packed	Medium cost, lens	Medium stowage	Good stowage	*High cost, lens and camera system*
Cost	Med.	Low	Med.	Med.	Low	*High*

Image 8. Review matrix and iteration of the potential design approaches

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Radientum
WIRELESS PERFORMANCE MATTERS

huld

WP1 - Mission concepts consolidation

Fourth step: Two mission concepts identified

1. **In-Orbit Servicing**
   - Refueling Operations
   - Hardware Upgrades
   - Debris Removal
   - Anomaly Resolution
   - Assembly of Large Structures
2. **Low-Lunar Orbit Navigation**
   - Lunar Surface Exploration
   - Sample Return Missions
   - Construction of Lunar Outposts
   - Lunar Resource Utilization
   - Lunar Satellites Maintenance

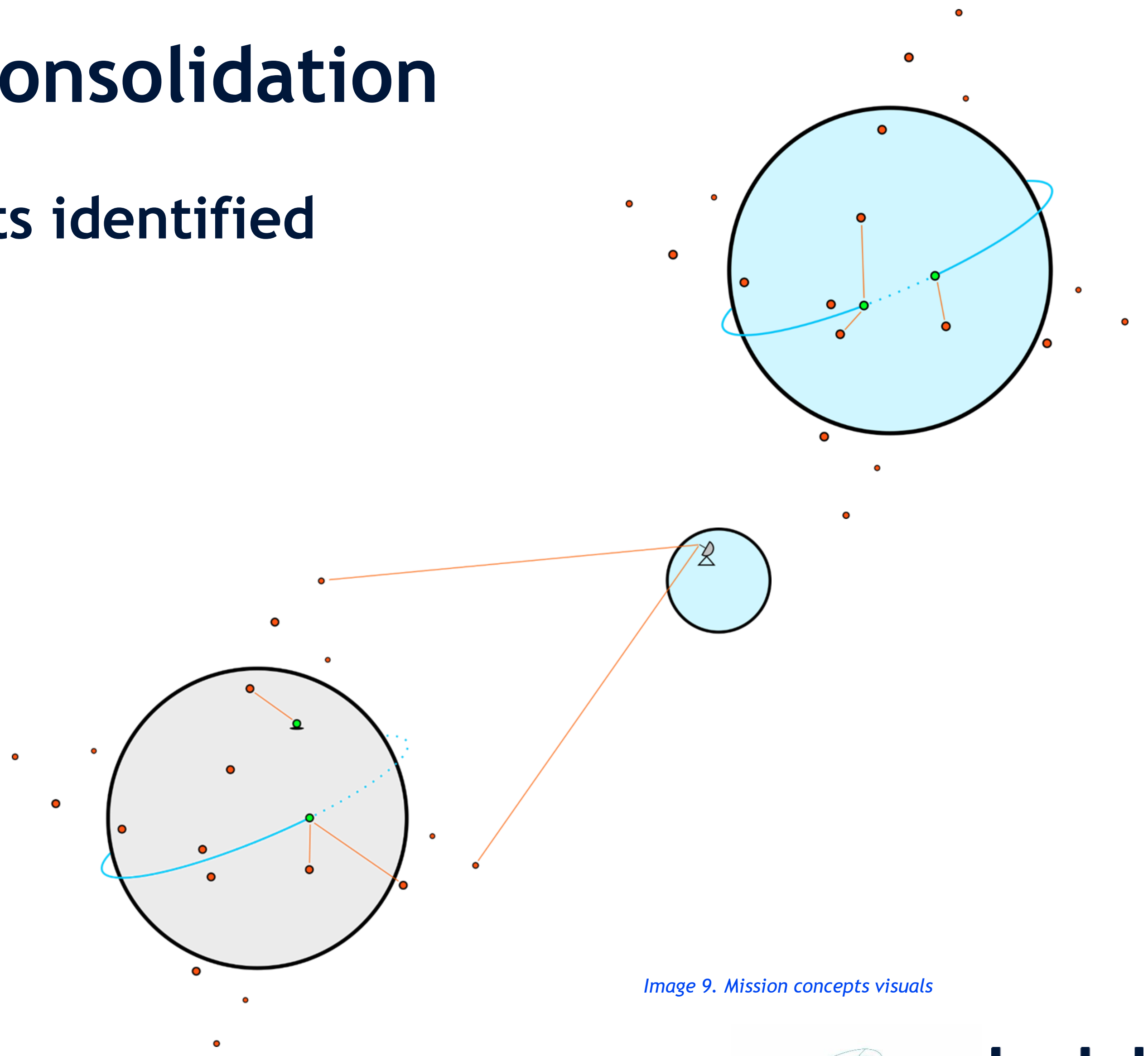


Image 9. Mission concepts visuals

ILMATIETEEN LAITOS METEOROLOGISKA INSTITUTET FINNISH METEOROLOGICAL INSTITUTE

Radientum

huld

WP1 - Consolidated antenna requirements, cluster configuration and verification plan

Consolidated set of antenna requirements establishing the specific requirements based on the most promising antenna and mission use cases that have been identified.

- **Requirements for:** Mission, Functional, Interface, Environmental, Operational, Physical, PA, Configuration, Design and Verification
- **Cluster configuration:** Provisional cluster configuration taking account e.g. complexity, tracking efficiency and beam
- **Verification plan:** Model philosophy, verification methods and strategy, verification tools, verification control methodology and verification matrix
- **Consolidated breadboard antenna requirements** for the project outcome product

WP 2 - Trade-off Analysis of Preliminary Antenna Designs

WP1			WP2			WP3				WP4						WP5	
Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sept-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sept-25
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18

Recap of the work purpose and content

- Preliminary design of antenna concepts and trade-off analysis of potential antenna and deployment concepts
- Decision of the best antenna concept for detailed design in WP3

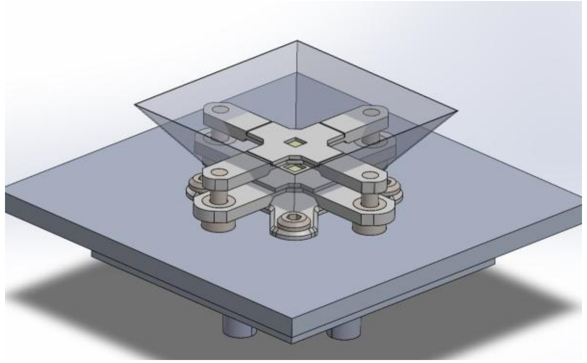


Image 10. Mechanical concept 1.1

huld

WP2 – Mechanical concepts

- Three main concepts were:
  - Deployable stacked patch antenna.
  - Deployable metallic horn fed with a patch antenna.
  - Deployable lens fed with a patch antenna.

Image 11. Mechanical functional prototypes

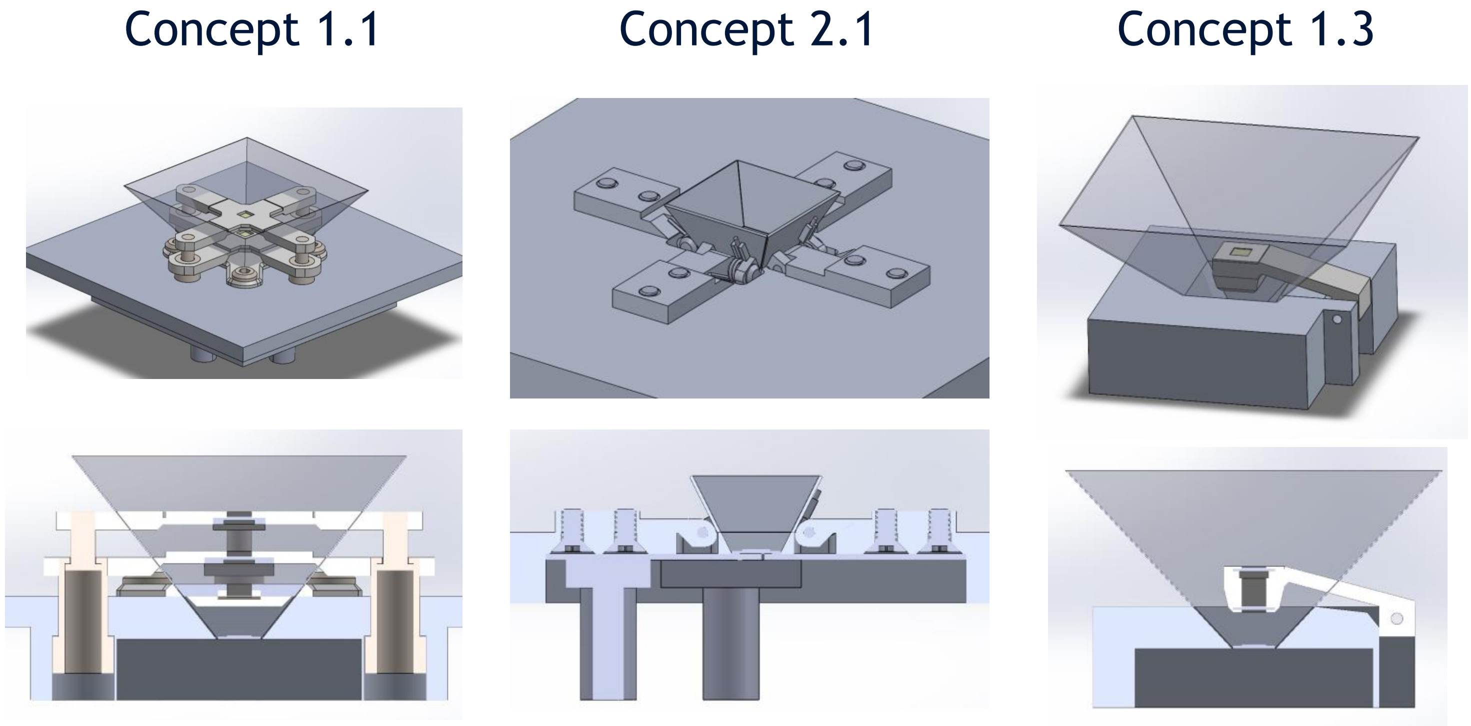


Image 12. Mechanical concepts

WP2 – Trade-off analysis

- Both electrical and mechanical analyses were conducted with weighted values
  - Value weighting were formed to reflect the S-o-W requirements
  - Electrical analysis was conducted through electromagnetic simulations against 9 criteria
  - Mechanical analysis was conducted through concept modeling against 12 criteria
- Concept 1.1 Stacked patches antenna was chosen to be the best concept for detailed design in WP3

	Criteria and short description	Weight importance	Concept 1.1	Concept 1.2	Concept 2.1	Concept 1.3	Concept 3.0	Single patch
ELECTRICAL PARAMETERS	Gain (RHCP / LHCP)	1	4	3	4	5	3	1
	Mechanical sensitivity	1	2	2	4	N/A	N/A	N/A
	Bandwidth	0,75	4	4	4	4	3	4
	Beamwidth (max. - min. gain diff)	0,75	5	4	4	1	2	2
	Phase stability	0,75	5	4	5	3	3	5
	Axial ratio	0,5	5	1	4	1	3	5
	Max. gain scalability	0,5	3	4	2	N/A	N/A	N/A
	Phase centre stability	1	4	4	4	3	2	4
	Group delay stability	0,5	3	4	4	2	2	5
	Sum of scores	6,75	26,00	22,50	26,75	15,50	13,50	18,25
	Relative score	...	3,85	3,33	3,96	2,95	2,57	3,48
MECHANICAL PARAMETERS	Structure complexity	0,75	3	2	2	5	N/A	N/A
	Robustness and rigidity	1	4	3	3	4	N/A	N/A
	Deployment complexity	0,75	3	3	1	5	N/A	N/A
	Deployment accuracy	1	5	4	4	4	N/A	N/A
	Manufacturability	0,75	3	2	1	5	N/A	N/A
	Material requirement	0,75	3	3	5	4	N/A	N/A
	Cost estimate	0,5	3	2	1	5	N/A	N/A
	Packing efficiency	0,5	2	3	5	2	N/A	N/A
	Size	1	4	3	5	4	N/A	N/A
	Mass	1	3	2	5	4	N/A	N/A
	Thermal stability	1	4	3	4	1	N/A	N/A
	Environmental compatability	0,5	3	2	4	2	N/A	N/A
	Sum of scores	9,5	33	26	32,75	35,75	N/A	N/A
	Relative score	...	3,47	2,74	3,45	3,76	N/A	N/A

		Concept 1.1	Concept 1.2	Concept 2.1	Concept 1.3	Concept 3.0
Combined score (Electrical weight 1, mechanical weight 1.5)	...	3,62	2,98	3,65	3,44	2,57
Placement	...	2	4	1	3	5

Additional criteria	Weight importance	Concept 1.1	Concept 2.1
Business opportunity	0,125	4	3
Overall risk	0,25	3	2
Electrical score	1	3,85	3,96
Mechanical score	1,5	3,47	3,45
Sum of scores	2,875	10,31	10,01
Relative score	...	3,58	3,48
Placement	...	1	2

Image 13. Compiled trade-off analysis

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Radientum

huld

WP 3 - Deployable Antenna Detailed Design

WP1			WP2			WP3				WP4						WP5	
Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sept-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sept-25
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18

Recap of the work purpose and content

- Detailed design of the chosen antenna concept with the help of simulations to be ready for breadboard manufacturing.
- Creating test plan for the breadboard antenna.

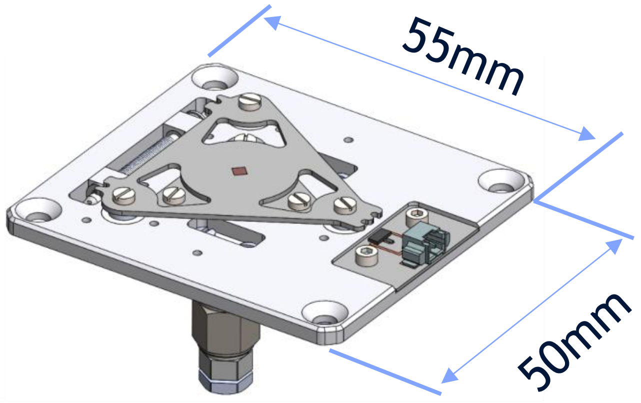
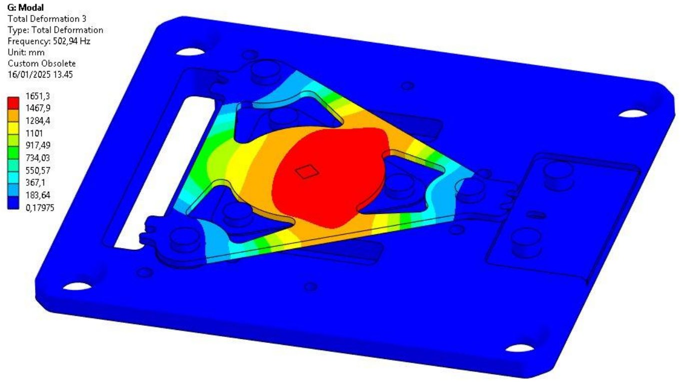


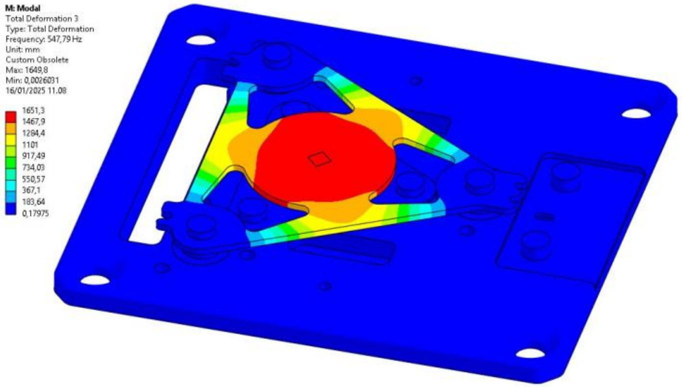
Image 14. Stacked patch antenna

WP3 – Mechanical design

- A mechanical design was created to be used as a base model for electrical, structural and thermal simulation.



Modal analysis, stowed = 503 Hz



Modal analysis, deployed = 548 Hz

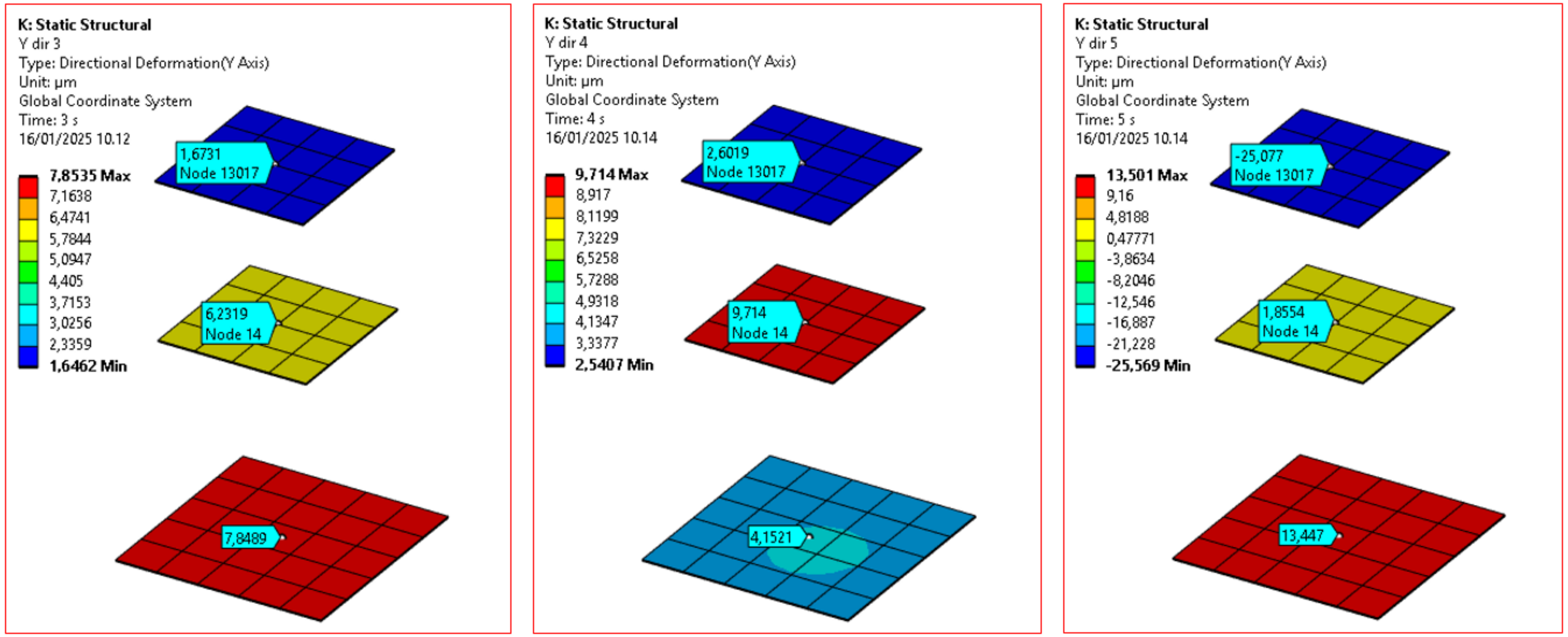


Image 15. Thermal simulations

WP3 – Electromagnetic design

- Figure shows the electromagnetic simulation model of the antenna.
- The antenna consists of two stacked parasitic patches to guide the radiation (light pink plates in the figure), and a feeding patch antenna PCB attached to the bottom of the structure.
- The feeding antenna PCB includes RF-connectors and a microstrip 90-degree hybrid.
- Electromagnetic simulations were also done to consider the mechanical variations from the mechanical simulations.

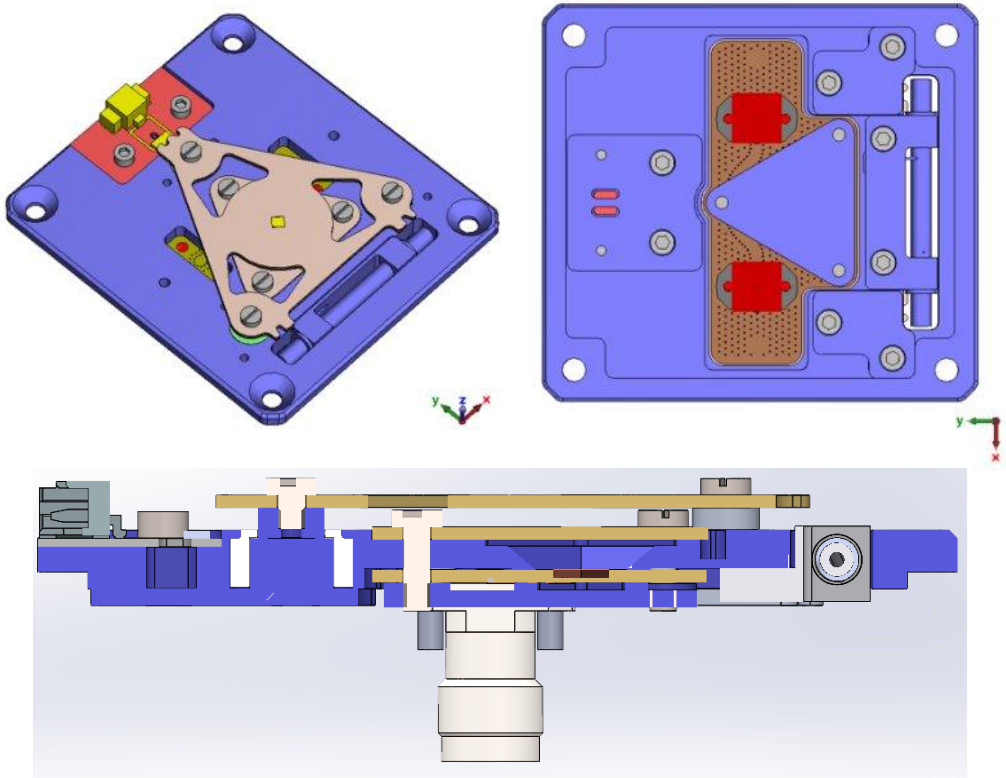


Image 16. Antenna simulation model

WP3 - Additional wave traps

- The -3dB beamwidth was not fully compliant over all the 3D-pattern cut angles. Reason was excited surface waves in the structure.
- The aluminum structure was modified to increase the beamwidth. This was done by smoothing the aluminum structure and introducing additional wave traps.
- When wave traps were used the minimum beamwidth increased to around the targeted level. This result is shown in the right most figure (smoothed connector and wave trap).

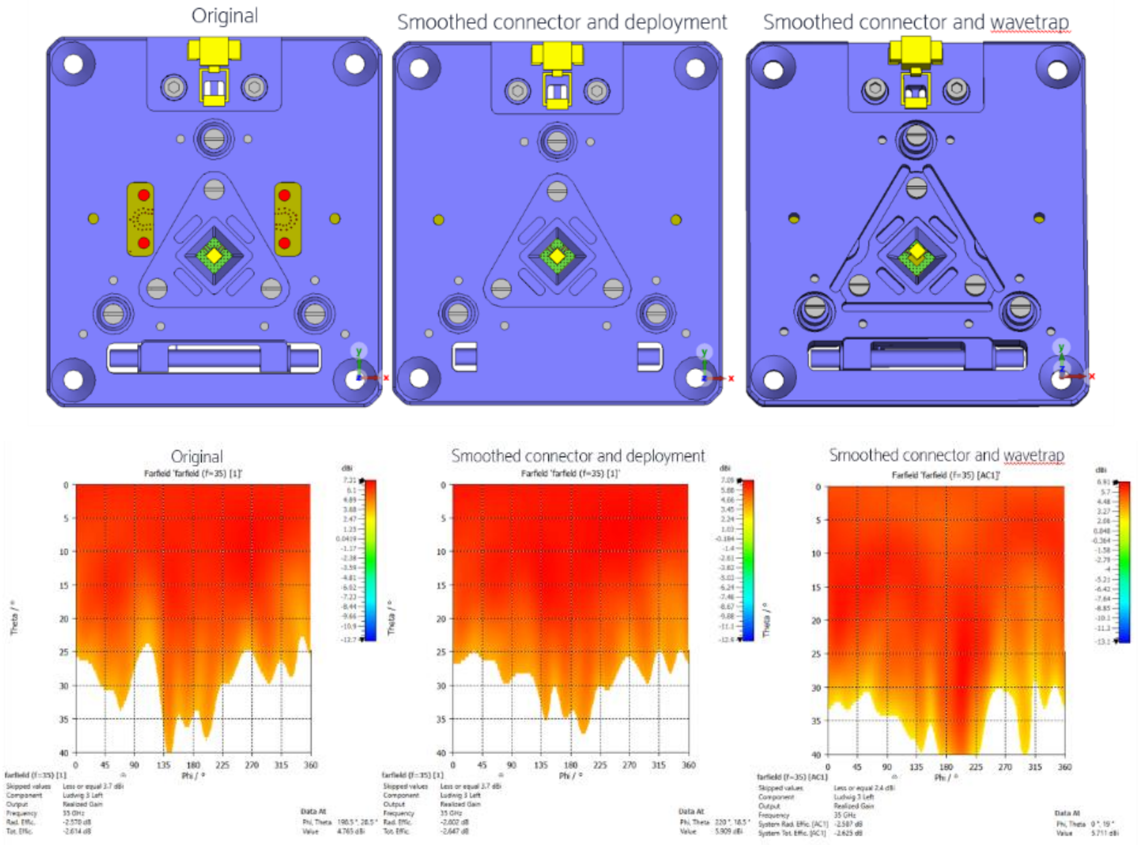


Image 17. Beamwidth analysis

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Radientum

huld

WP4 – Manufacturing and testing

WP1			WP2			WP3				WP4						WP5	
Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sept-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sept-25
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18

Recap of the work purpose and content

- Breadboard manufacturing and product assembly
- Antenna performance verification through mechanical and electrical testing

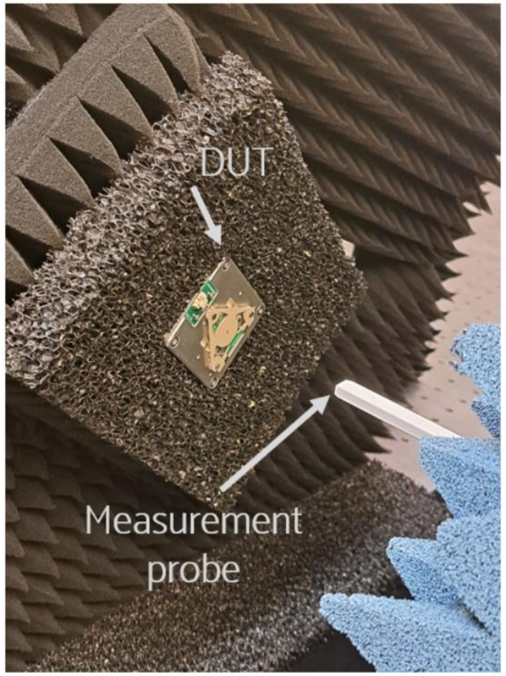


Image 18. Aalto test setup

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE
Radientum
huld

WP4 – Manufacturing and testing

- Two base plate manufacturing rounds
  - Changes done on the antenna base plate on the second manufacturing round – added wave traps.
- Single PCB manufacturing round
  - Risk mitigation: Several size variants of the critical PCB parts.
- RF testing was performed at Aalto University and at ESA ESTEC facilities.

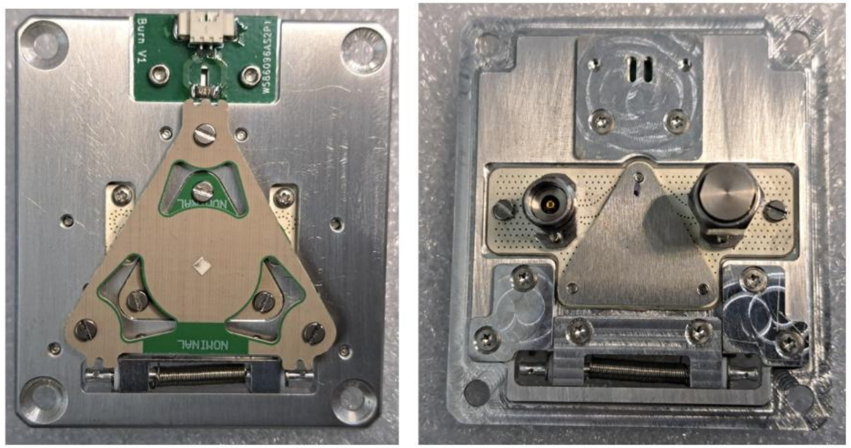


Figure 19. Antenna without additional wave trap.

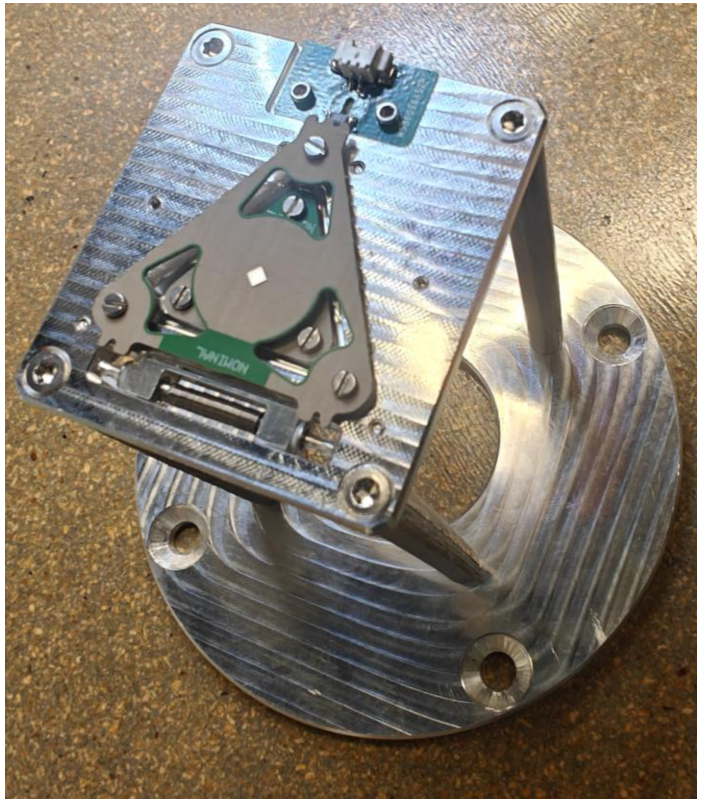


Figure 20. Antenna installed to the test setup.

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Radientum

huld

WP4 – Mechanical testing

- MECH-02 and MECH-05 requirements were verified through testing in Work Package 4.
- For MECH-02 requirement the mass of the antenna was measured. The mass without coaxial connectors is 24 grams.
- For MECH-05 requirement the antenna was stowed and deployed more than ten times consecutively.

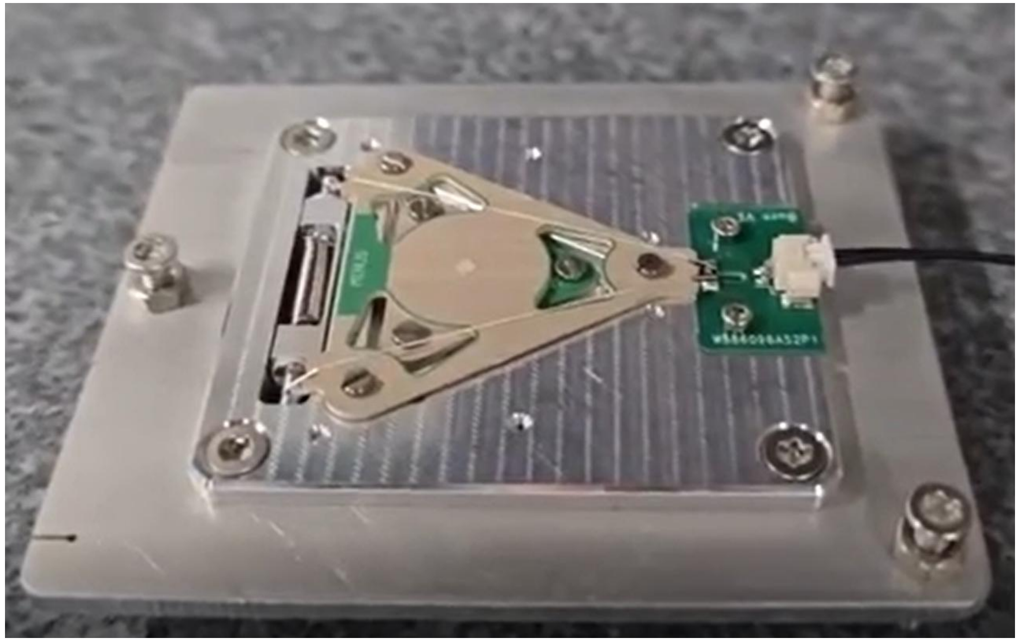


Image 21. Antenna in stowed configuration

ILMATIETEEN LAITOS METEOROLOGISKA INSTITUTET FINNISH METEOROLOGICAL INSTITUTE

Radientum WIRELESS PERFORMANCE MATTERS

huld

WP4 - Mechanical compliance analysis

- MECH-02 and MECH-05 were verified through testing in Work Package 4.

Requirement	Description	Note	Compliance to specification
MECH-01	The stowed antenna shall be compatible with a 'n x 10cm' Cubesat	Size of the stowed antenna breadboard is 50mm x 55mm x ~8mm. For flight model, the size can be optimized further	YES
MECH-02	The mass of the antenna shall be minimised to be suitable for a 'n x 10cm' Cubesat	Mass for the breadboard antenna is under 50 grams, which is suitable for Cubesat format	YES
MECH-03	The temperature range the feed shall be operational over shall be -120 + 120 C	According to thermal analysis, compliance can be achieved in RF performance and deployment of the mechanism	YES
MECH-04	The antenna stability (Thermoelastic and in-orbit perturbations) will be less than 100/wavelength	Natural frequency of the antenna is relatively high (over 500Hz) in deployed state of the antenna. Thermal stability of the antenna assembly is according to analysis stable	YES
MECH-05	The minimum number of stowage and deployment cycles (On ground) will be greater than 10	All of the deployment tests have been succesful with over 10 deployment tests	YES
MECH-06	The antenna will be suitable for low earth orbit	Material choices have been made with leo environment compatibility	YES
MECH-07	The minimum natural frequency in deployed configuration should be higher than 0.5Hz	According to FEM analysis natural frequency of the deployed antenna is 550Hz, well over the required 0,5Hz	YES
MECH-08	The minimum natural frequency in stowed configuration should be higher than 100Hz	According to FEM analysis natural frequency of the deployed antenna is 550Hz, well over the required 0,5Hz	YES

Image 22. Mechanical compliance analysis

WP4 – Electrical testing at Aalto

- The purpose of Aalto University measurements was to confirm antenna functionality before ESTEC measurements.
- Measurements at Aalto University were done using VNA and a planar near-field scanner.
- Proper PCB variant chosen for ESTEC measurements: Antenna with larger feeding antenna (plus size).
    - Furthermore, two aluminum base plate variants: One with additional wave traps (AUT1), and the other without (AUT2).

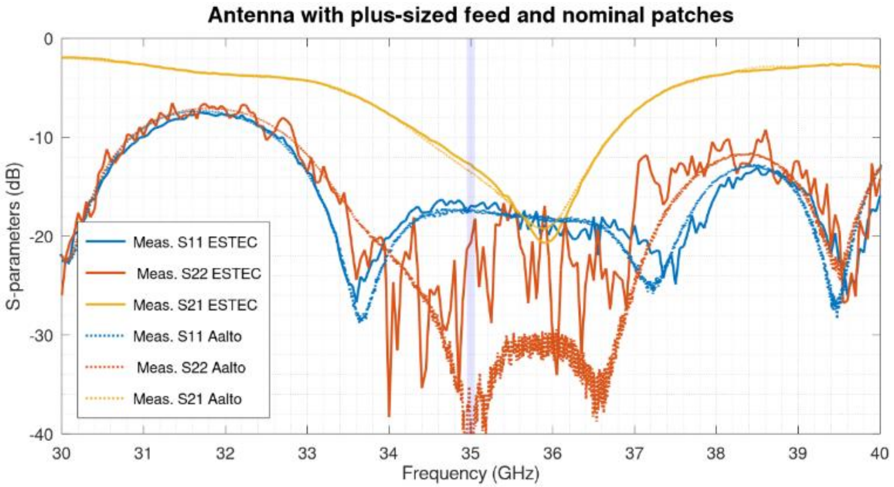


Image 23. Aalto & ESTEC Measurement results

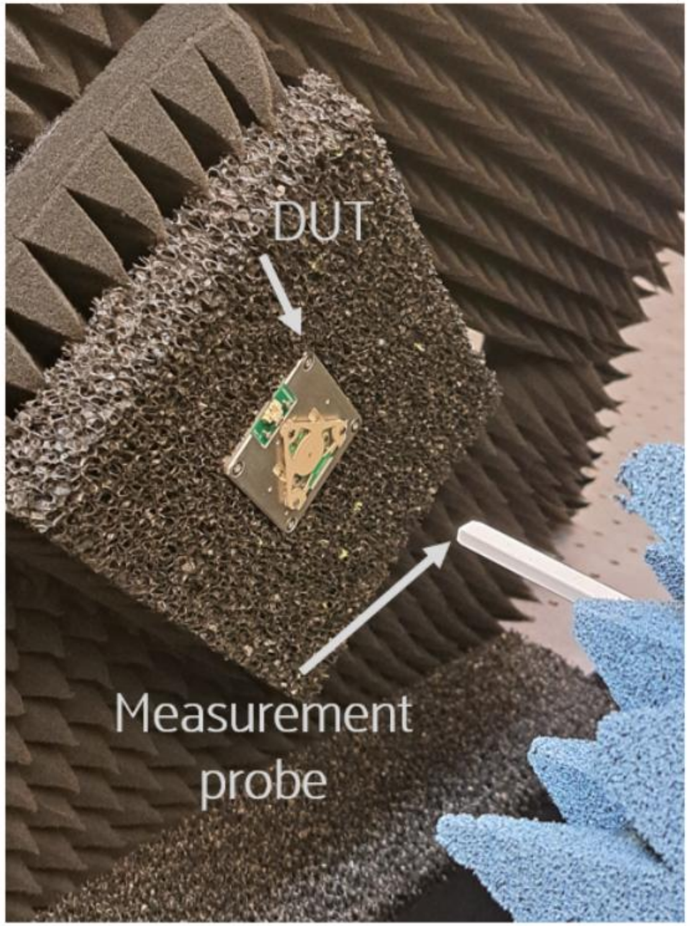


Image 24. Aalto test setup

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE
Radientum
huld

WP4 - Electrical testing at ESTEC

- ESTEC measurements were used to estimate the performance of the antenna against the requirements.
- Overall, there was reasonable correspondence between Aalto and ESTEC measurements.
- Measurements showed that additional wave traps helped in achieving larger beamwidth. Figure shows the measured 3D realized gain patterns at 35 GHz with the wave traps.

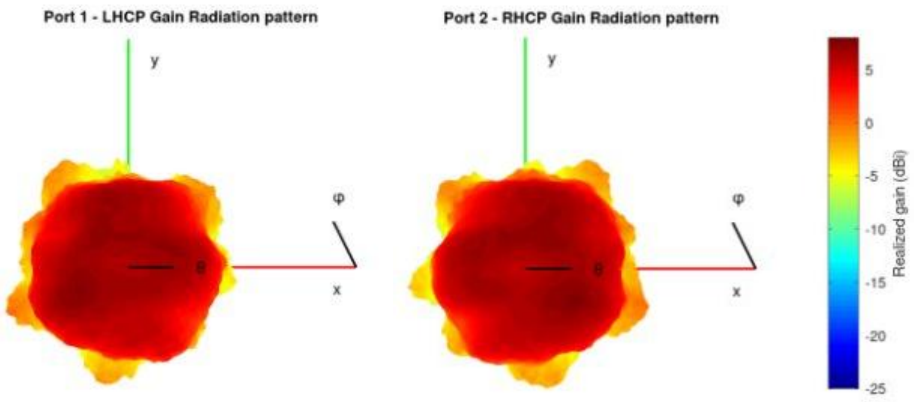


Image 25. 3D realized gain patterns at 35 GHz with the wave traps

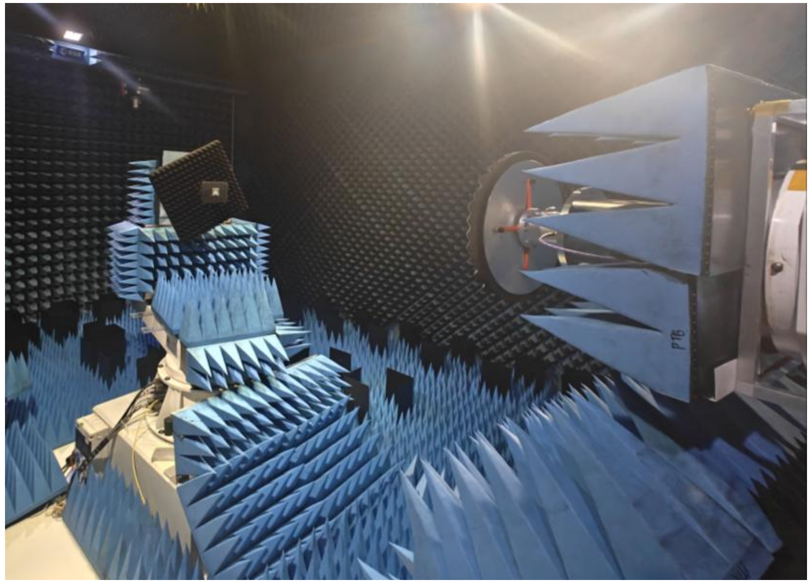


Image 26. Measurement setup inside ESTEC spherical near-field range

WP4 – Electrical compliance analysis after measurements

- Antenna with additional wave traps chosen for compliance comparison.
- The antenna is almost fully electrically compliant.
  - The minimum beamwidth is slightly less for LHCP.
  - The axial ratio is slightly above the target at the beam edge for RHCP.
- Accurate group delay measurement very challenging at Ka-band. ESTEC accuracy is 2 ns.

			Specification		
Requirement	Description	Additional Notes:	Port 1 Values	Port 2 Values	Within specification
ELEC-01	The antenna shall be dual circularly polarized.		LHCP	RHCP	YES
ELEC-02	The antenna shall operate in Ka-Band.	Operating band 34.95-35.05 GHz	34.95-35.05 GHz	34.95-35.05 GHz	YES
ELEC-03	The -3-dB beamwidth of the antenna shall be +/- 30 degrees.	The values shown are minimum beamwidths compared to broadband gain.	Minimums -28 and 30 deg. Averages -35.8 and 34.9 deg. (3.0 dBi - 6.3 dBi)	Minimums -30 and 31 deg. Averages -37.2 and 36.3 deg. (2.9 dBi - 5.8 dBi)	Partial
ELEC-04	The antenna bandwidth greater than 100 MHz.	Effective bandwidth 100 MHz	100 MHz	100 MHz	YES
ELEC-05	The variation in phase over the field of view shall be +/- 1 mm over azimuth and elevation.	Corresponds to +/- 42 = 84 degree phase variation.	< 62.5 deg.	< 69.9 deg.	YES
ELEC-06	The phase centre stability shall be less than 5 mm over operational temperatures.	Measured at nominal temperature in mechanical boresight. *Simulated over frequency and temperature variation of -120 - 120 °C in mechanical boresight.	Meas. < 1 mm. *Sim. < 2.5 mm.	Meas. < 1 mm. *Sim. < 2.5 mm.	YES
ELEC-07	The group delay stability over phi and theta shall be less than 1 cm.	The group delay stability of 1 cm translates to 33 ps in free space. Measured only in broadside. *Simulated variation over field-of-view. **Simulated variation for temperature variation over field-of-view.	Meas. 2 ps. *Sim. 15 ps. **Sim. 50 ps.	Meas. 2 ps. *Sim. 5 ps. **Sim. 50 ps.	YES
ELEC-08	Return loss of the antenna shall not be less than 15 dB.	Reported in 100 MHz bandwidth.	>15.0 dB	>15.0 dB	YES
ELEC-09	The axial ratio of the antenna shall be <= 6 dB within FoW.	Reported values for primary cut planes.	1.5-6.0 dB	0.4-8.8 dB	Partial

Image 27. Electrical compliance after measurements

Next steps

WP5 - Exploitation of innovation

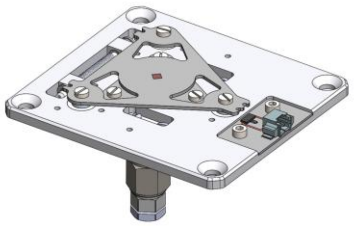
WP1			WP2			WP3				WP4						WP5	
Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sept-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sept-25
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18

Recap of the work purpose and content

- Explanation of how the PNT innovation studied and developed can be used to form the basis for a proposal submission in future development projects to raise product TRL level
- Critical assessment of the potential of the developed product for commercial exploitation to bring them to market readiness

Image 28. Deployable Satellite Navigation Antenna

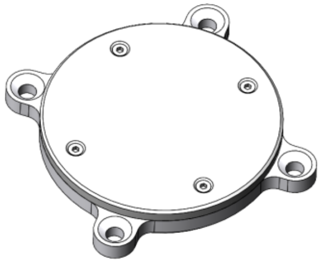
Future project scenarios



Scenario 1: Flight preparation of current design (TRL4 → TRL6)

This scenario uses tested and validated RF design with conventional materials and manufacturing technologies. It offers reliability but provides low benefit from the deployment mechanism compared to its risks and complexity.

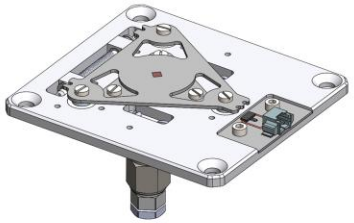
Next steps: Update wire retractor, optimize design with additional manufacturing rounds, perform testing and validation, and integrate with CubeSat for flight.



Scenario 2: Fixed antenna version (TRL3 → TRL6)

A robust, compact, and low-cost antenna structure with a failsafe design. It allows easy frequency range shifts with minor design changes and has strong business potential. The antenna is tiny and lightweight but requires full development, design, and testing.

Next steps: Integrate RF design into a fixed antenna, optimize design through manufacturing rounds, validate performance, and prepare CubeSat integration.



Scenario 3: Frequency scaling (TRL2 → TRL4 → TRL6)

This concept scales mechanical structures for robustness and easier manufacturing. It supports lower frequency bands (Ku-band) and offers potential for a more beneficial deployment mechanism. However, the application scenario remains unclear, and development is needed.

Next steps: Frequency scaling to lower Ku-band, optimize structure and design through manufacturing rounds, manufacture breadboard, perform testing and validation, and integrate with CubeSat.

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Radientum

huld

Q/A & Contact details

huld

Juho Veteläinen - juho.vetelainen@huld.io
Jaakko Kaartinen – jaakko.kaartinen@huld.io

Radientum

Mikko Kärnä Leino – mikko.leino@radientum.fi
Riku Kormilainen – riku.kormilainen@radientum.fi

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Harri Haukka – harri.haukka@fmi.fi
Antti Kestilä – antti.kestila@fmi.fi