NAVISP-EL1-018

Low-RF

Fast Deployable Systems for Emergencies in Difficult Environments

Final Presentation
10/06/2022

AALBORG UNIVERSITY
DENMARK

gmv NSL

Agenda

Introduction

Project plan

Work summary

Main conclusions and way forward

Questions & Answers

Project Introduction

Project objective

- Crisis modes are unexpected and can take place anywhere and anytime.

> "[…] it is clear that current solutions, especially GNSS-based ones, are not adequate to support the navigation functions required for crisis modes."
>
> GMV NSL & AAU @ ION GNSS+ 2022

- The objective of this contract is to design and develop a PoC for a Civilian and Assets Recovery System (CARS), conformed by two main elements:
  - **C**risis **R**ecovery and **E**mergency **A**ssistance and **M**anagement segment (**CREAM**). System transmitter.
  - **D**evice for the **R**ecovery and **E**mergency **A**ssistance and **M**anagement segment (**DREAM**). System receiver.

AALBORG UNIVERSITY DENMARK

gmv NSL

Agenda

Introduction

Project plan

- **Project overview**
- **Project work structure**
- **Overview of conducted tasks**

Work summary

Main conclusions and way forward

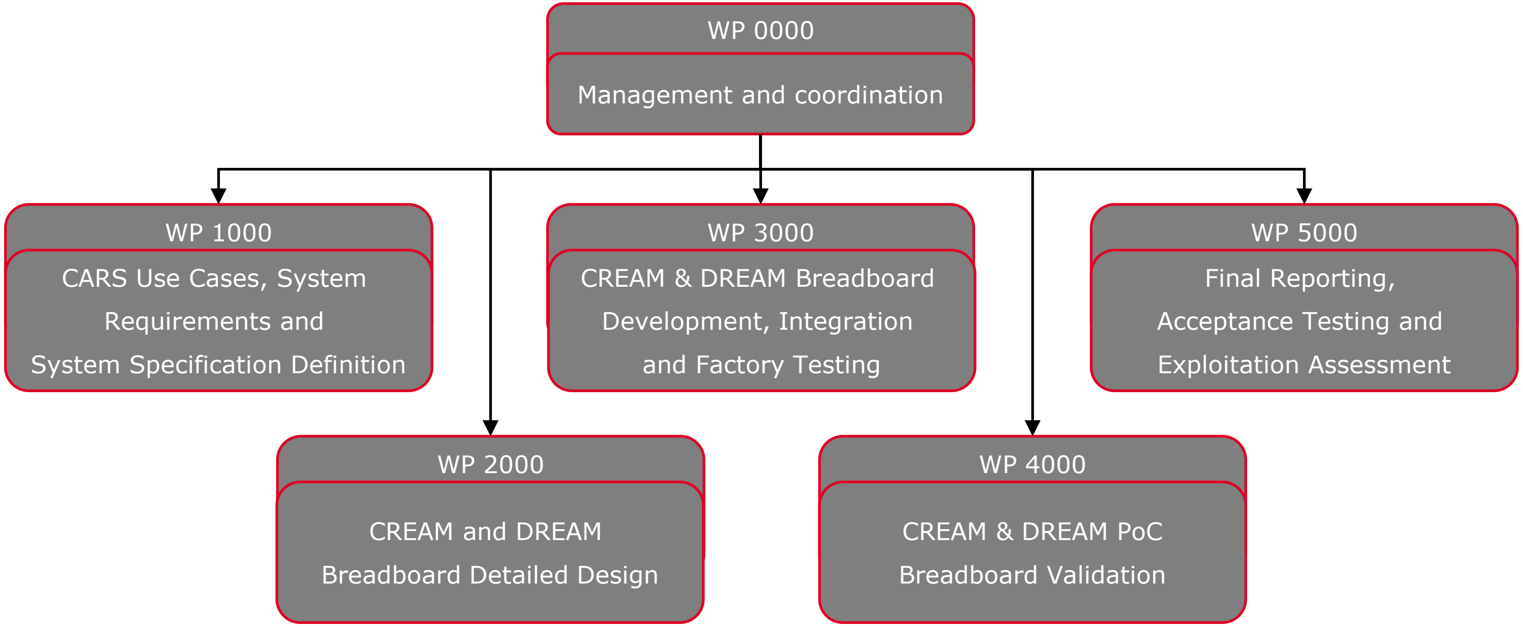
Questions and Answers

Project plan

Project overview

Project plan

Project work structure



Project plan

Overview of conducted tasks

WP 1000
CARS Use Cases, System Requirements and System Specification Definition

- Review of existing recovery systems.
- Selection of targeted CARS scenarios.
- Experimentation and validation plan outline.

WP 2000
CREAM and DREAM Breadboard Detailed Design

- CARS system design.
- Hosting platform trade-off study.
- System architecture trade-off structure.

WP 3000
CREAM & DREAM Breadboard Development, Integration and Factory Testing

- CARS implementation.
- CARS system assessment.
- Performance study.

WP 4000
CREAM & DREAM PoC Breadboard Validation

- System validation execution.
- Controlled-environment and indicative experimentation.
- Experimentation campaign detailed definition.

WP 5000
Final Reporting, Acceptance Testing and Exploitation Assessment

- Experimentation campaign execution.
- Controlled-environment and indicative experimentation.
- Experimentation campaign detailed definition.

Agenda

Introduction

Project plan

Accomplished work

- **State-of-the-art review, scenario selection**
- **System definition, design, development and validation**
- **Real-world experimentation**

Main conclusions and way forward

Questions and Answers

Accomplished work

State-of-the-art review, scenario selection (1/4): Crisis recovery systems

Crisis recovery systems	Link Topology			Antenna conf.		Operation freq. [MHz]	Link budget figures		Mobility	
	Position		Tx-Rx Elev. angle	Tx	Rx		Tx. power [W]	Coverage [km]	Tx	Rx
	Tx	Rx								
Walkie- Talkies	O/I	O/I	Low	Omni	Omni	27, 49, ~460, ~900	0.5 – 5	~30	Static	Static
Amateur Radio	O	O	Variable	Omni	Omni	~140, ~440	up to 1500	>100	Static	Static
Trunking Radio	O/I	O	Low	Omni	Omni	~ 400, ~900	1.8	~60	Semi static	Static
COWs	O/I	O	Low	Omn	Omni	Variable	up to 100	5 -10	Semi static	Static
Satellite Phones	O	O	Variable	Omni	Drt	~1616 - 1626.5	up to 7	Global	Semi static	Mobile
MANET	O	O	Low	Omni/Drt	Drt	30 - 5000	~ 1.5	Variable	Semi static	Semi static
BSNET	O/I	O/I	Low	Omni	Omni	Variable	up to 100	Variable	Semi static	Static
Wireless Mesh	O/I	O/I	Low	Omni	Omni	Variable	~0.5	Variable	Semi static	Semi static
Wireless Balloon	O	O/I	High	Omni	Omni	Variable	up to 2.5	80	Static	Mobile

- There is no universal emergency/crisis recovery system able to operate in all environments.
- Focused on outdoor communications.
- Systems heavily network infrastructure dependant.

AALBORG UNIVERSITY DENMARK

gmv NSL

Accomplished work

State-of-the-art review, scenario selection (2/4): GNSS systems

GNSS	Link Topology			Antenna conf.		Operation freq. [MHz]	Link budget figures		Accuracy [m]	Mobility	
	Position		Tx-Rx Elev. angle	Tx	Rx		Tx. Power [W]	Coverage [km]		Tx	Rx
	Tx	Rx									
GPS						L1: 1575.42 L2: 1227.6 L5: 1176.45	50 - 240		3		
GLONASS						L1:1602 L2: 1246 L3:1201	20 - 135		2		
Galileo	O	O	High	Drt	Omn	L1: 1575.42 E5: 1191.795 E6: 1278.75	95 - 160	Global	1	Mobile	Semi static Mobile
BeiDou						B1: 1575,42 B2:1191,79 B3: 1 268,52	130 - 185		1		
IRNSS						L: 1164-1189 S: 2483.5-2500	40 - 120	Regional	10 - 20		

- Global Navigation Satellite Systems (GNSS) provides useful positioning information in crisis situations.
- Coverage is global, but subjected to non-cluttered outdoor environments.
- Cluttered environments degrade performance -> there is a reliability on terrestrial infractucture.

Accomplished work

State-of-the-art review, scenario selection (3/4): IPS systems

<table>
<tr><th rowspan="3">IPS</th><th colspan="3">Link Topology</th><th colspan="2">Antenna conf.</th><th rowspan="3">Operation freq.[GHz]</th><th colspan="2">Link budget figures</th><th rowspan="3">Accuracy [m]</th><th colspan="2">Mobility</th></tr>
<tr><th colspan="2">Position</th><th rowspan="2">Tx-Rx Elevation angle</th><th rowspan="2">Tx</th><th rowspan="2">Rx</th><th rowspan="2">Tx. power [mW]</th><th rowspan="2">Coverage [m]</th><th rowspan="2">Tx</th><th rowspan="2">Rx</th></tr>
<tr><th>Tx</th><th>Rx</th></tr>
<tr><td>RFID</td><td rowspan="9">I</td><td rowspan="9">I</td><td rowspan="9">Low</td><td>Drt</td><td>Omn</td><td>~0.9</td><td>1000</td><td><1</td><td>0.5</td><td rowspan="8">Static</td><td rowspan="9">Semi static

Mobile</td></tr>
<tr><td>BLE</td><td>Omni/Drt</td><td>Omni/Drt</td><td>2.4</td><td>0.005 - 3.2</td><td>>50</td><td>2 - 4</td></tr>
<tr><td>Wi-Fi</td><td>Omni/Drt</td><td>Omn</td><td>2.4, 5</td><td>100</td><td>>150</td><td>5 - 15</td></tr>
<tr><td>ZigBee</td><td>Omn</td><td>Omn</td><td>0.7 - 0.9, 2.4</td><td>10-100</td><td>10 - 20</td><td><1</td></tr>
<tr><td>UWB</td><td>Drt</td><td>Drt</td><td>3.1-10.6</td><td>0.5</td><td>10 - 150</td><td>0.001</td></tr>
<tr><td>IR</td><td>-</td><td>-</td><td>400000</td><td>-</td><td rowspan="2">Limited to line-of-sight</td><td><1</td></tr>
<tr><td>VLC</td><td>-</td><td>-</td><td>450000-790000</td><td>-</td><td><1</td></tr>
<tr><td>Ultra-sound</td><td>-</td><td>-</td><td>0.001-0.01</td><td>-</td><td>-</td><td><1</td></tr>
<tr><td>Magnetic</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td><2</td><td>-</td></tr>
</table>

- RF-base indoor localization is accurate only when using UWB technologies.
- There is no universal PNT system that operates in all scenarios.

Accomplished work

State-of-the-art review, scenario selection (4/4): Conclusions

Conclusions

- Next generation CARS should be able to operate in any type of disaster scenarios.
- Other scenarios where GNSS-based navigation/current IPS are not reliable should be also considered.

- Focus is to be put in **challenging scenarios**, with a system able to operate in:
  - **Urban scenarios** such as urban canyons or extremely shadowed/cluttered positions.
  - **Disaster scenarios**, which typically present different propagation profiles.

This aforementioned puts the focus in **indoor and deep-indoor** scenarios.

Accomplished work

System definition, design, development and validation (1/5): CREAM & DREAM selection

- Software Defined Radio (SDRs) were chosen for the PoC hardware.
  - It is widely known the broad configuration range and reliability that SDRs provide.

USRP E312
(CREAM, transmitter)

USRP X310
(DREAM, receiver)

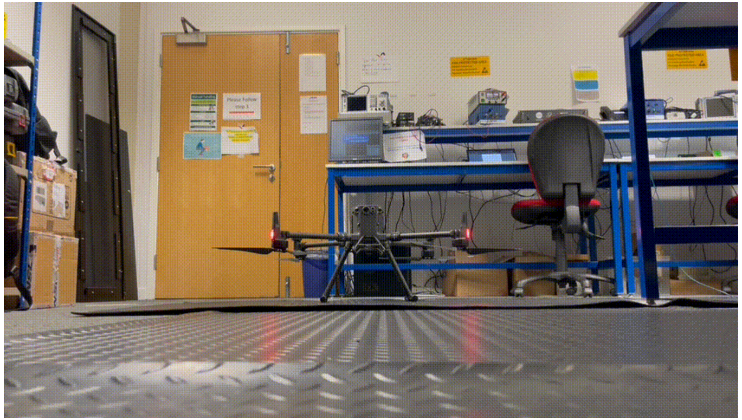
Accomplished work

System definition, design, development and validation (2/5): CREAM platform selection

Study was undertaken in order to find out the most suitable CREAM platform, based on the following KPIs:

- Cost
- Weight it can carry
- Size it can accommodate
- Antenna mountings it can offer
- Resilience to environmental conditions
- How rapidly it can be deployed
- Operational time
- Control range
- Dynamics
- Geometry diversity it can provide

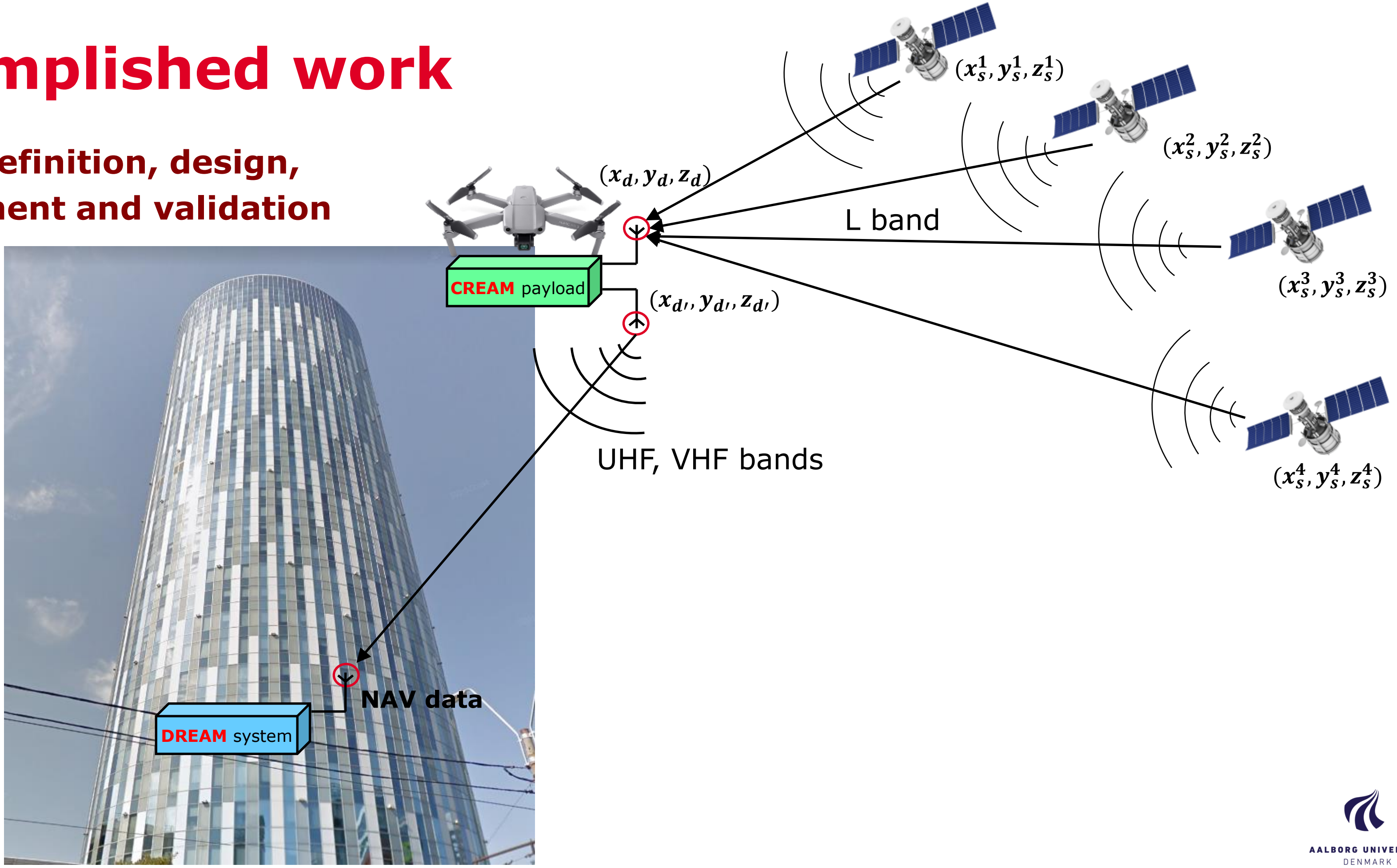
Drone stood out as the platform that provides better KPI trade-off.



First ever Low-RF drone test

Accomplished work

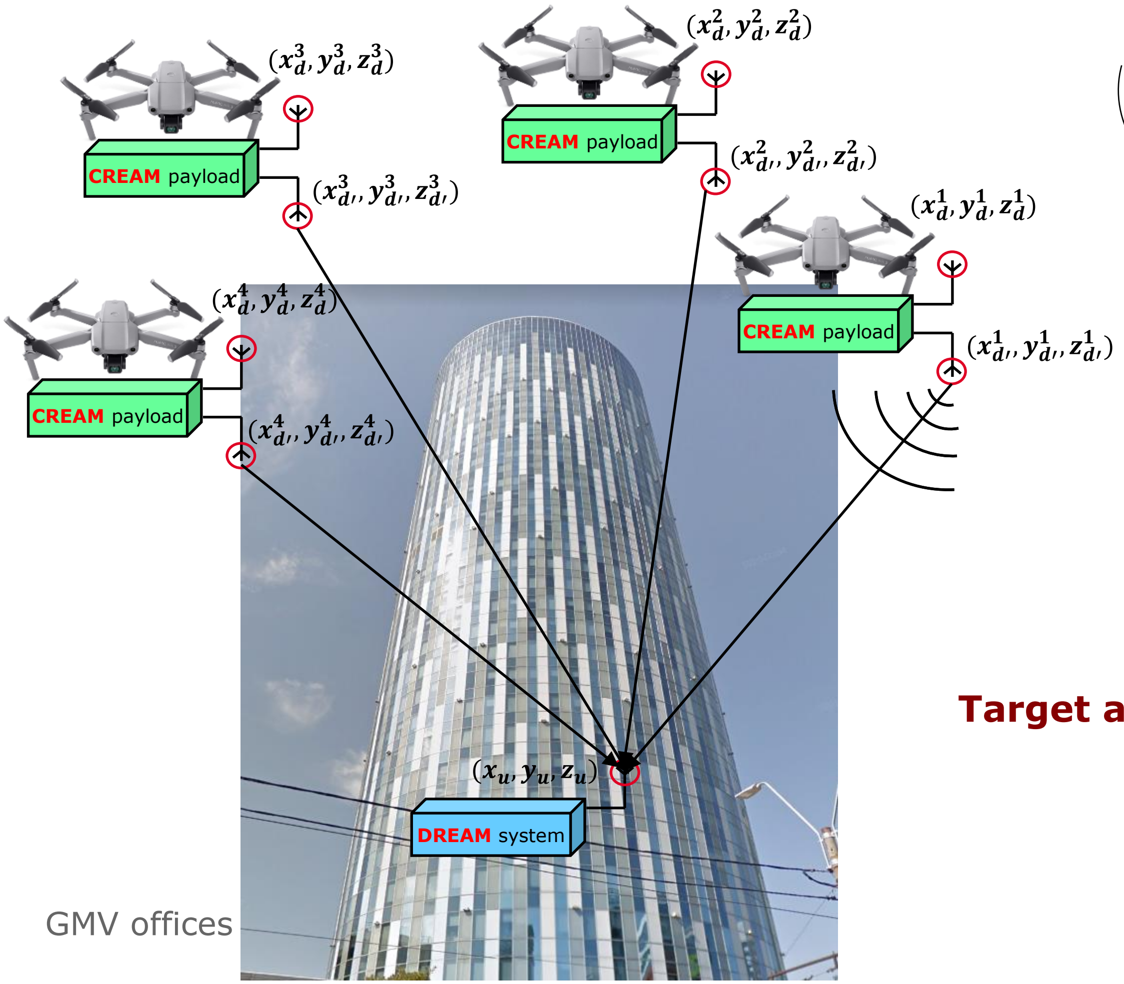
System definition, design, development and validation

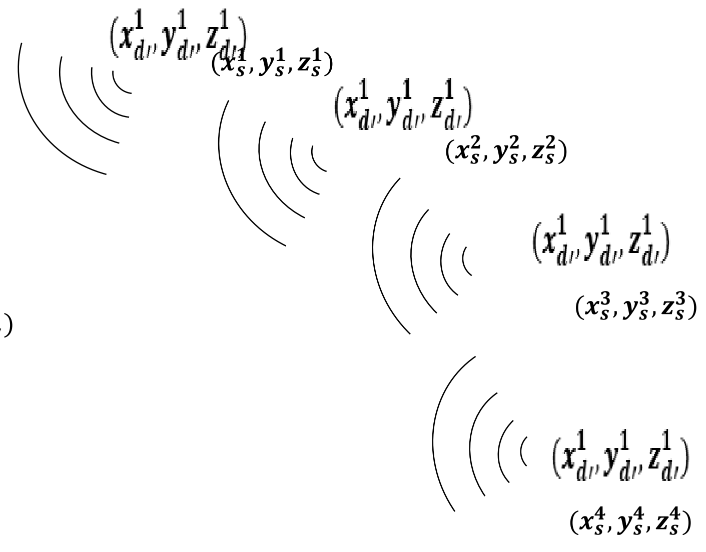


GMV offices

AALBORG UNIVERSITY DENMARK

gmv NSL



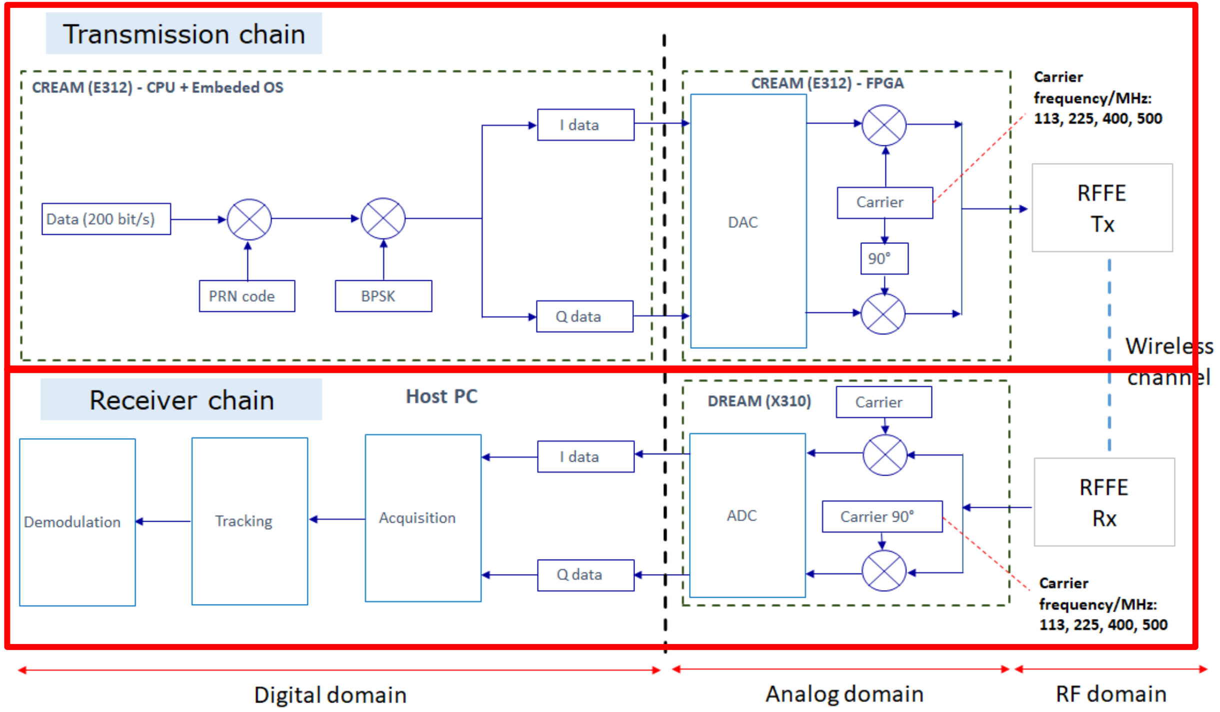


Target architecture

10/06/2022
AALBORG UNIVERSITY DENMARK
gmv NSL

Accomplished work

System definition, design, development and validation (3/5): CREAM – DREAM RF link



Accomplished work

System definition, design, development and validation (4/5): Signal propagation

Initially and taking ESA's input, three frequencies were selected for testing:

- 113 MHz (VHF)
- 225 MHz (VHF)
- 400 MHz (UHF)
- 500 MHz (UHF)

All the selected are allocated frequencies, UK Spectrum Regulator (OFCOM) was contacted in order to obtain test frequencies. OFCOM granted the following:

- 113 MHz
- 133 MHz
- 144 MHz
- 272.25 MHz
- 325 MHz
- 350.5 MHz
- 401.5 MHz
- 500 MHz

RETEVIS RT20 Dual-band 144 MHz / 430 MHz

RETEVIS RT1/3 UHF 400 MHz – 520 MHz

Accomplished work

System definition, design, development and validation (5/5): Frequency selection

- Distance: 8 m.
- Both CREAM and DREAM are located in the same corridor, facing each other in a straight line.
- Corridor setting is likely to cause impaired signal due to reflections.

Results summary

Antenna	Run#	Frequency /MHz	Bandwidth /MHz	Status	Description
SHORT antenna (Antenna 1)	1	113	10	OK	100 % worked
	2		1	N/A	Data not collected
	3	133	10	OK	100 % work
	4		1	N/A	Data not collected
	5	144	10	Fair	50 % work
	6		1	N/A	Data not collected
	7	272.25	10	N/A	Data not collected
	8		1	Bad	Worked < 50 % of success rate
	9	325	10	N/A	Data not collected
	10		1	Not OK	Did not work
	11	350.5	10	N/A	Data not collected
	12		1	OK	Worked > 90% success rate
	13	401.5	10	N/A	Data not collected
	14		1	Not OK	Did not work
LONG antenna (Antenna 2)	15	401.5	10	OK	Worked > 90 % success rate
	16		1	Not OK	Did not work
	17	500	10	OK	100 % work
	18		1	Not OK	Barely worked with < 10 % success rate

Accomplished work

System definition, design, development and validation (5/5): Frequency selection

Location	CREAM – DREAM distance	Surroundings	Comments
GMV NSL Nottingham	40 m	CREAM and DREAM are located in line of sight, with no obstacles.	-
GMV NSL Nottingham	60 m	CREAM and DREAM are located in line of sight, with no obstacles.	-

Results summary

Antenna	Run#	Frequency /MHz	Bandwidth /MHz	Status	Description
SHORT antenna (Antenna 1)	1	113	10	Fair	Worked with < 33 % success rate
	2	133	10	Ok	100 % worked
LONG antenna (Antenna 2)	3	401.5	10	Ok	Worked with > 80 % success rate
	4		1	Not ok	Worked with < 20 % success rate
	5	500	10	Ok	Worked 100 %
	6		10 (60m)	Ok	Worked 100 %
	7		1	Not ok	Work with < 50 % success rate

AALBORG UNIVERSITY DENMARK

10/06/2022

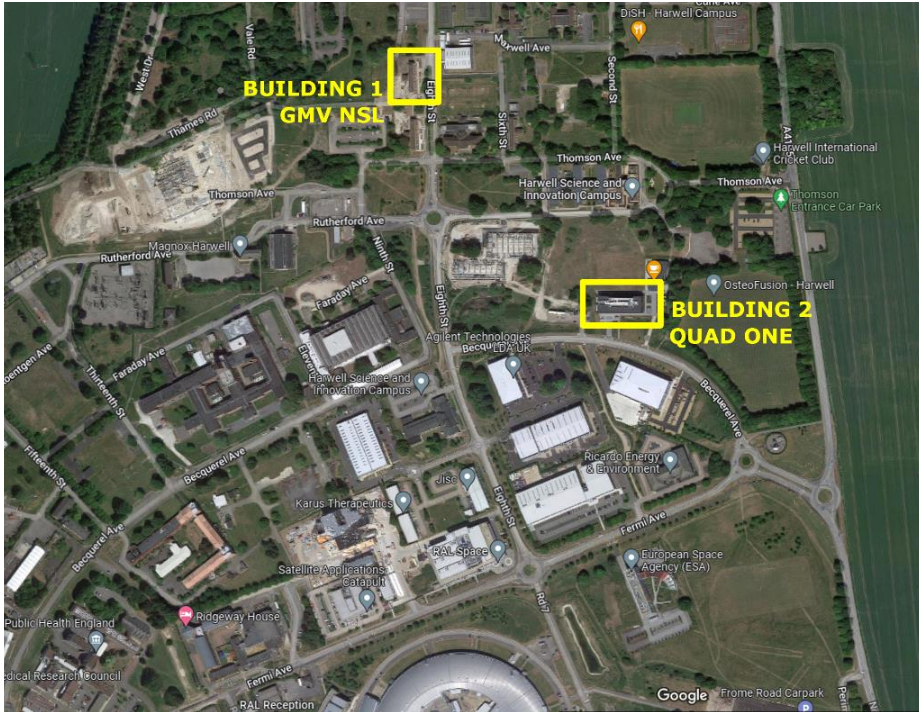
gmv NSL

Accomplished work

System definition, design, development and validation

Accomplished work

Real-world experimentation (1/8): Experimentation scenario overview



10/06/2022

AALBORG UNIVERSITY DENMARK

gmv NSL

Accomplished work

Real-world experimentation (2/8): Calibration

Traditional building

Thermo-efficient building

Accomplished work

Real-world experimentation (2/8): Calibration

Frequency	Effective penetration loss (traditional building)
133 MHz	10.4
401.5 MHz	16.0
500 MHz	8.6

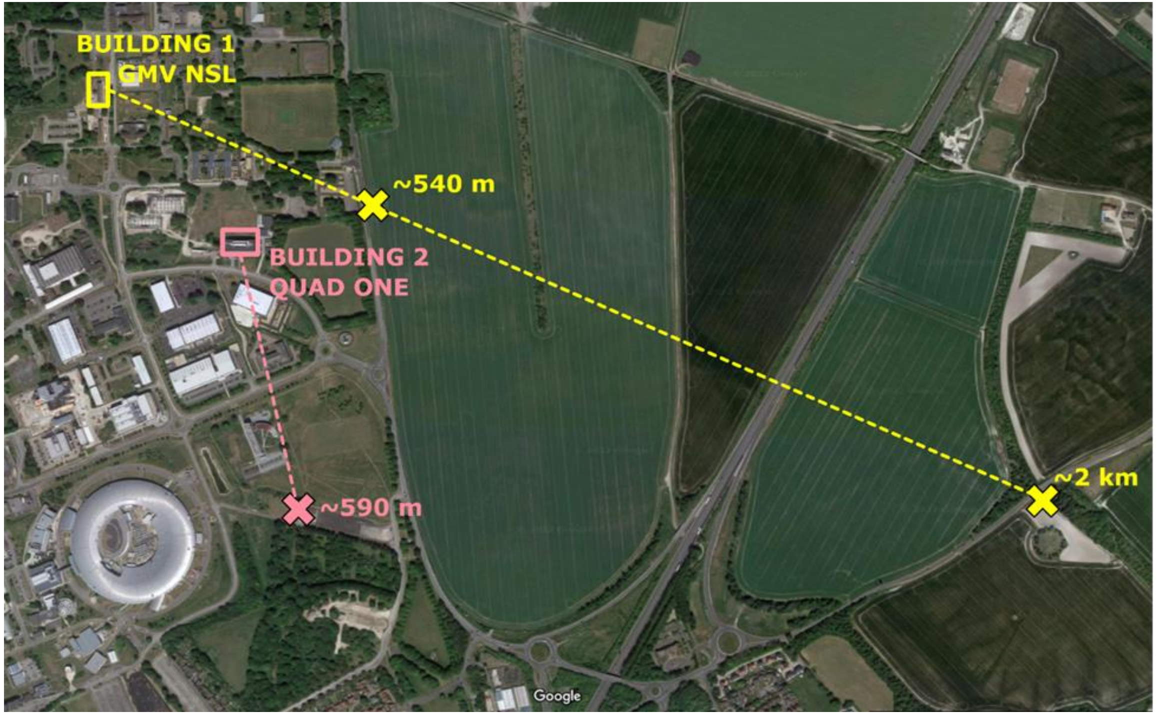
Frequency	Effective penetration loss (thermal-efficient building)
133 MHz	15.2 dB
500 MHz	25.2 dB

AALBORG UNIVERSITY
DENMARK

gmv NSL

Accomplished work

Experimentation results (3/8): System performance validation

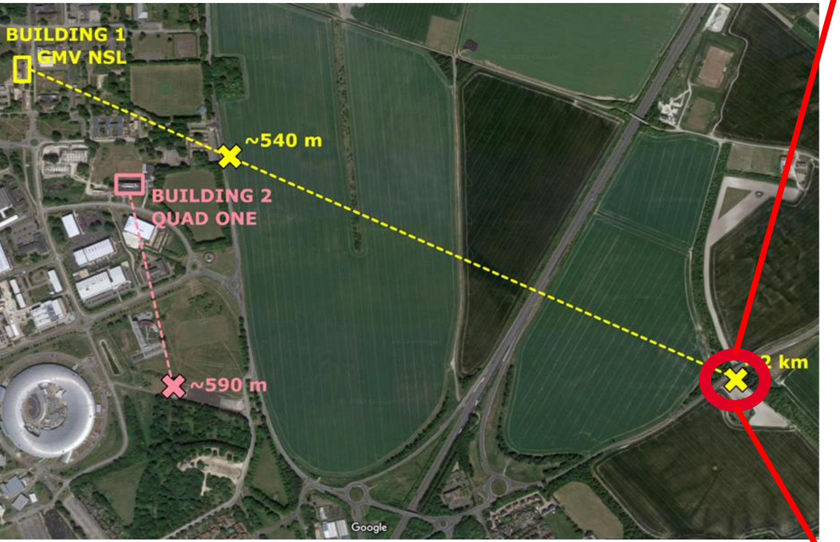


AALBORG UNIVERSITY
DENMARK

gmv NSL

Accomplished work

Real-world experimentation (3/8): System performance validation



gmv NSL

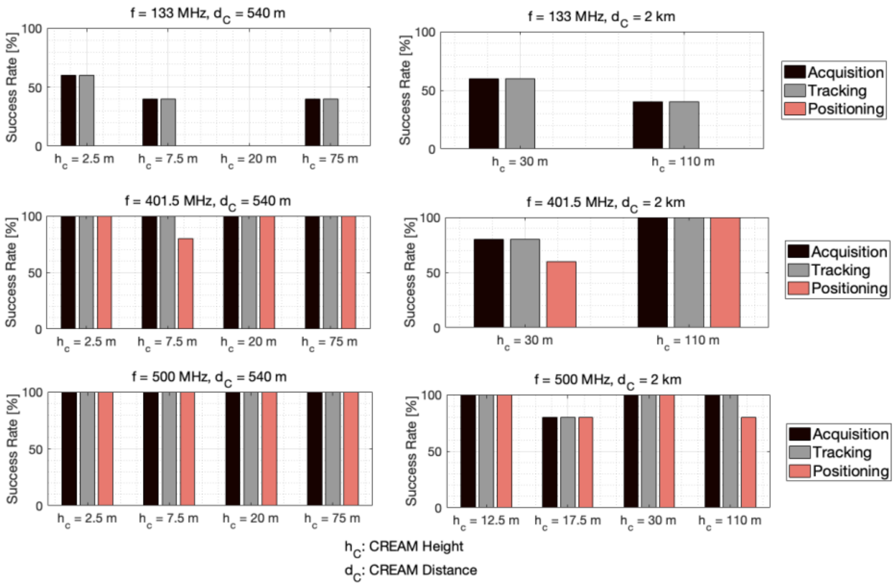
Accomplished work

Real-world experimentation (3/8): System performance validation

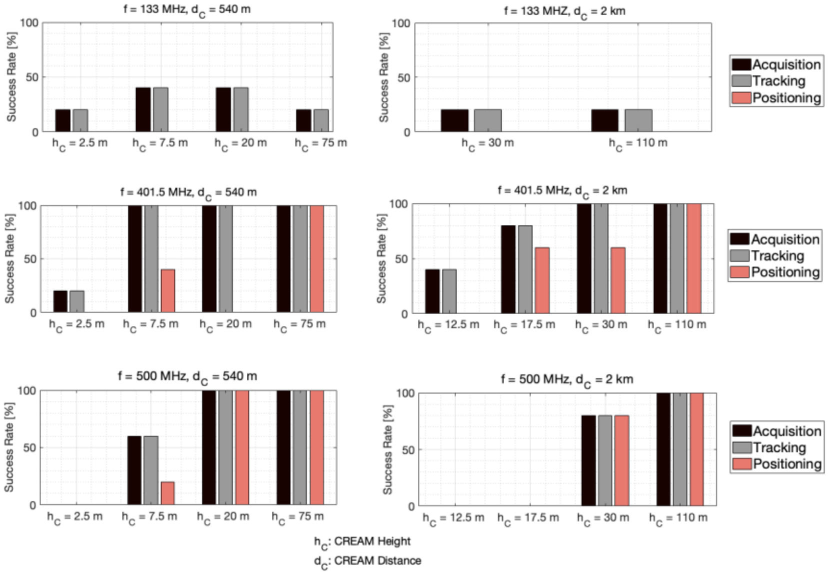
Accomplished work

Real-world experimentation (4/8): System performance validation results (traditional)

Outdoor scenario



Indoor scenario



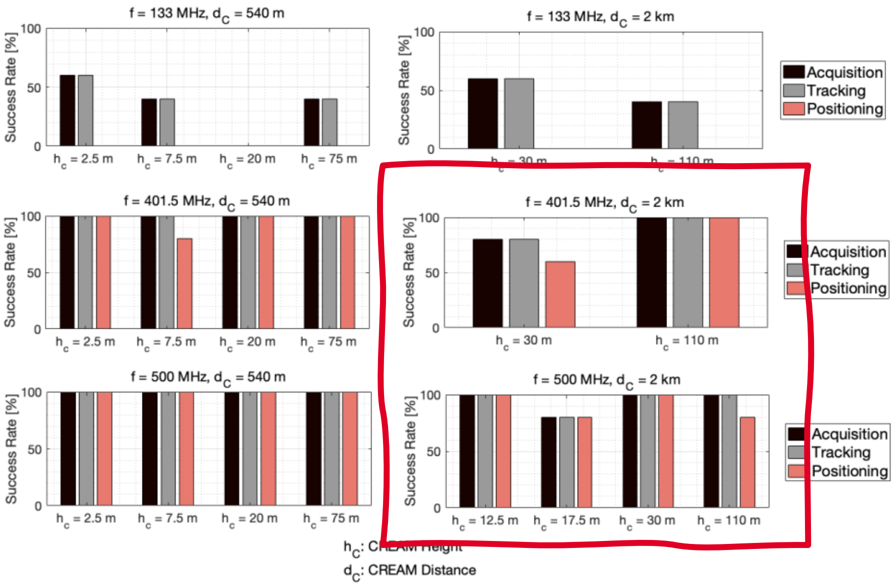
10/06/2022

DENMARK

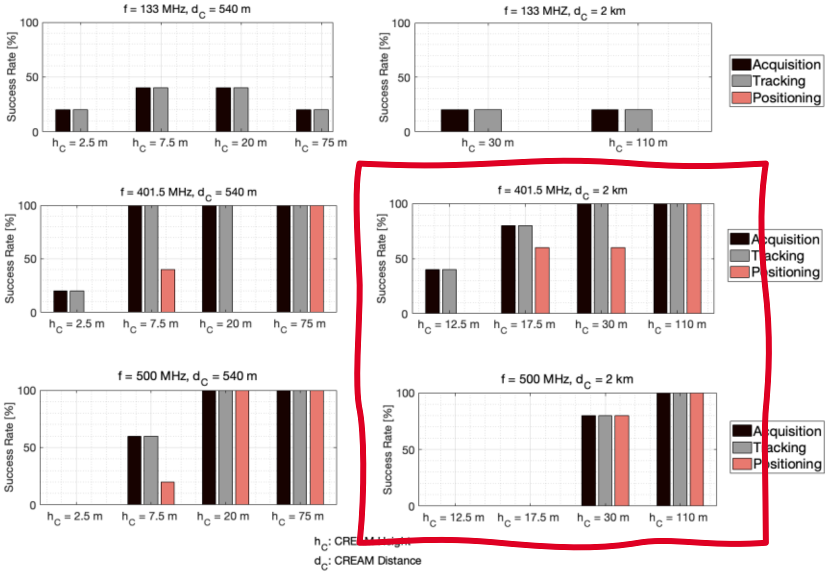
Accomplished work

Real-world experimentation (4/8): System performance validation results (traditional)

Outdoor scenario



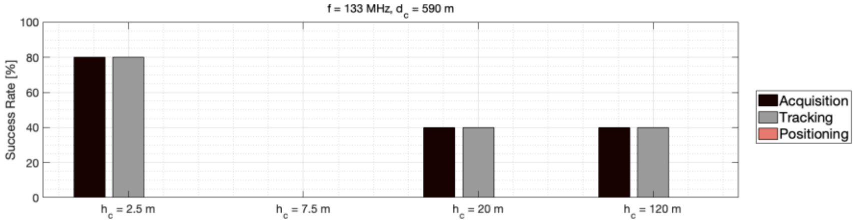
Indoor scenario

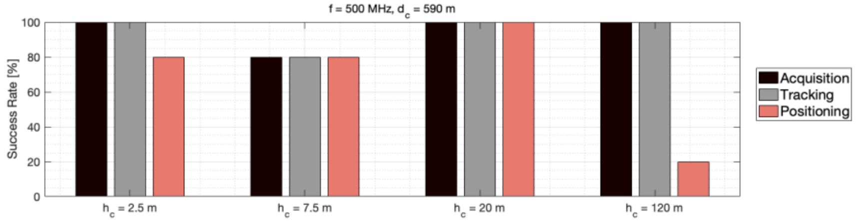


Accomplished work

Real-world experimentation (5/8): System performance validation results (thermo-eff)

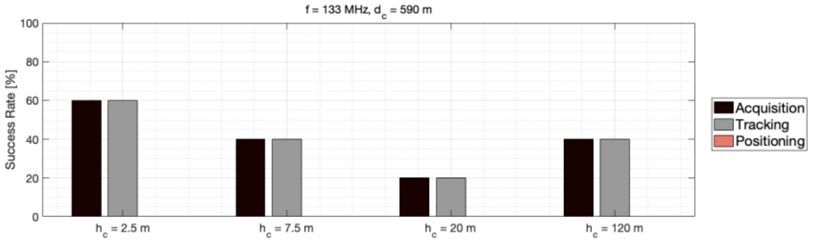
Outdoor scenario

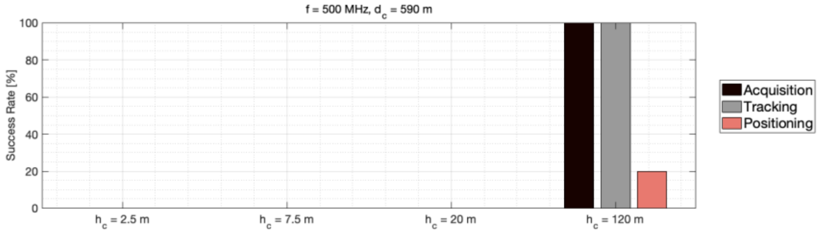




h_C: CREAM Height
d_C: CREAM Distance

Indoor scenario



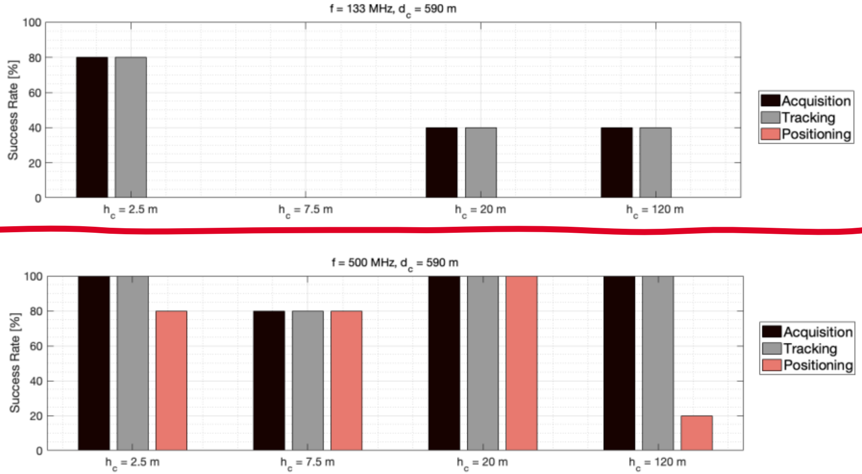


h_C: CREAM Height
d_C: CREAM Distance

Accomplished work

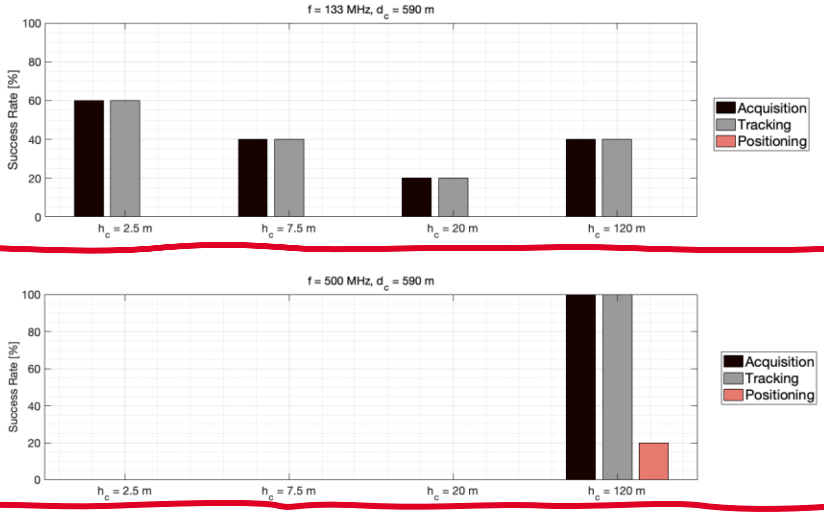
Real-world experimentation (5/8): System performance validation results (thermo-eff)

Outdoor scenario



h_c: CREAM Height
d_c: CREAM Distance

Indoor scenario



h_c: CREAM Height
d_c: CREAM Distance

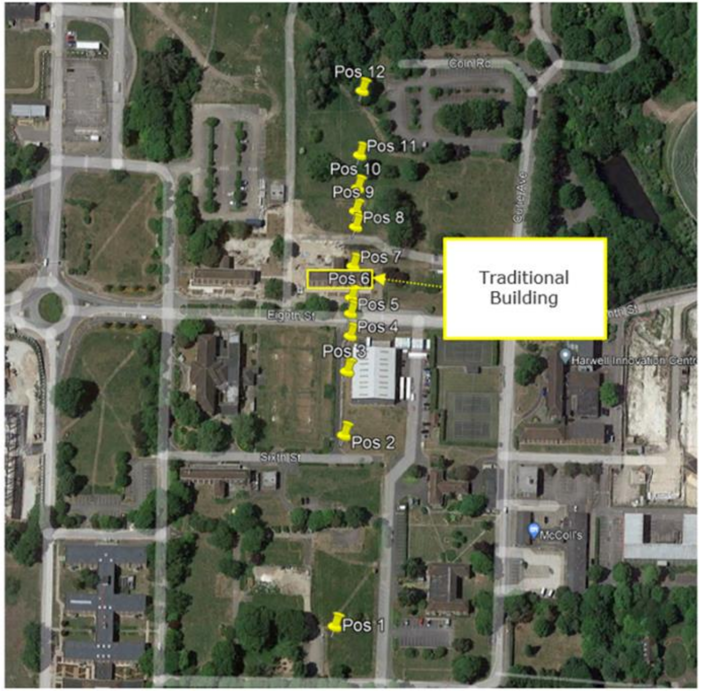
10/06/2022

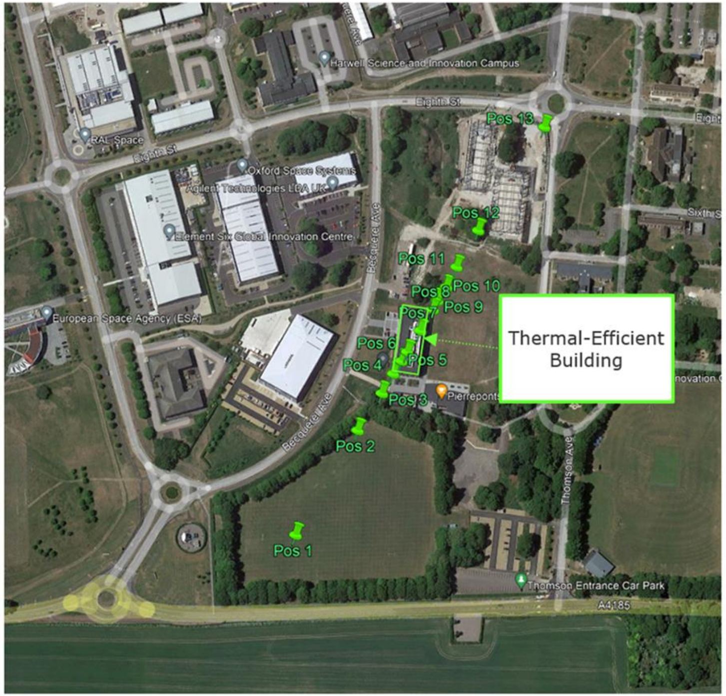
AALBORG UNIVERSITY DENMARK

gmv NSL

Accomplished work

Real-world experimentation (6/8): LEO pass emulation





10/06/2022

AALBORG UNIVERSITY
DENMARK

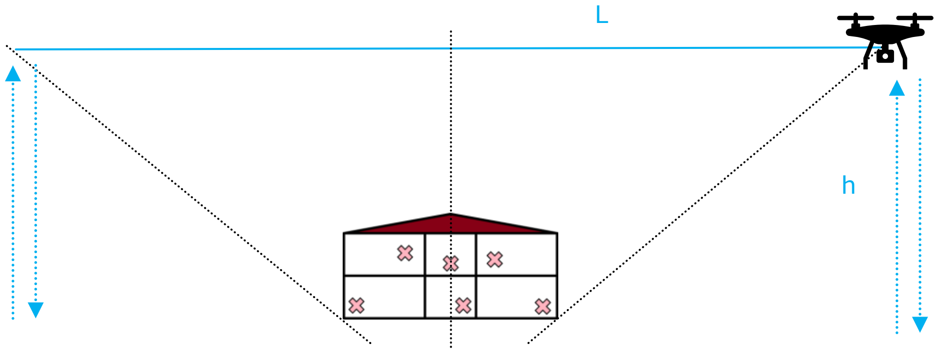
gmv NSL

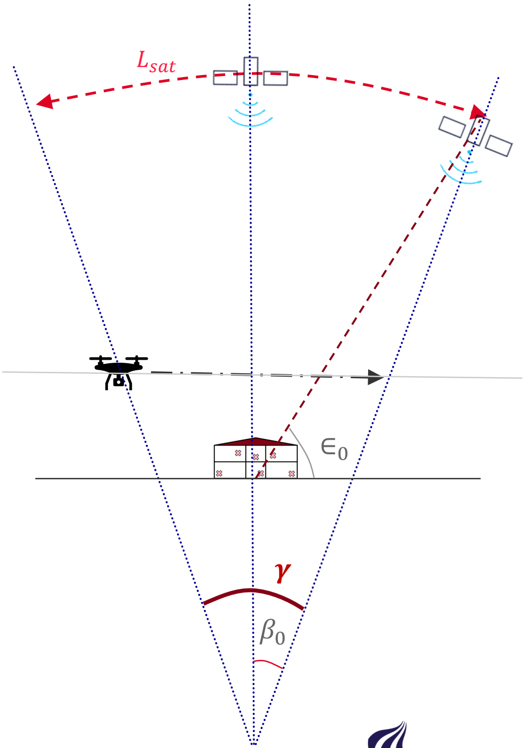
Accomplished work

Real-world experimentation (6/8): LEO pass emulation

- Projection of a LEO pass at 500 km into a 40 m height was carried out by extrapolating a LEO orbit into 40 m height and map associated positions

Elevation range evaluated corresponds to [10º, 170º]

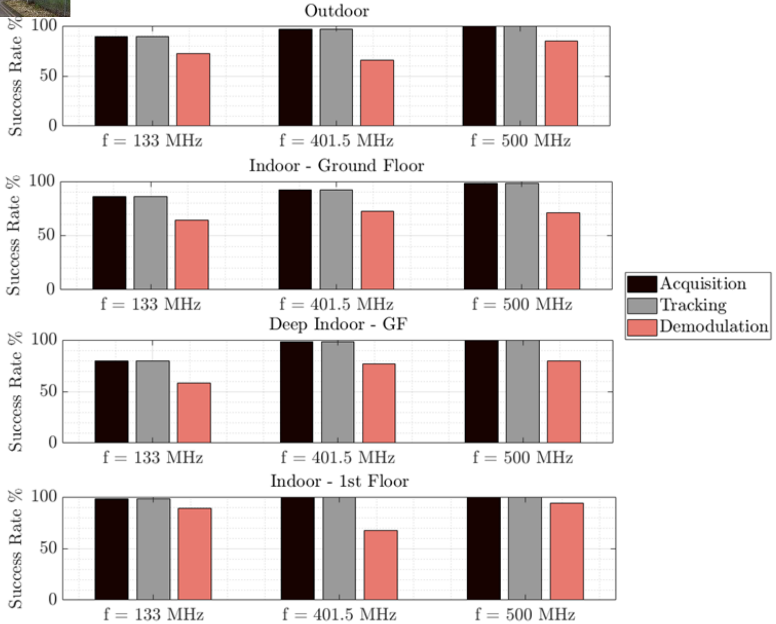




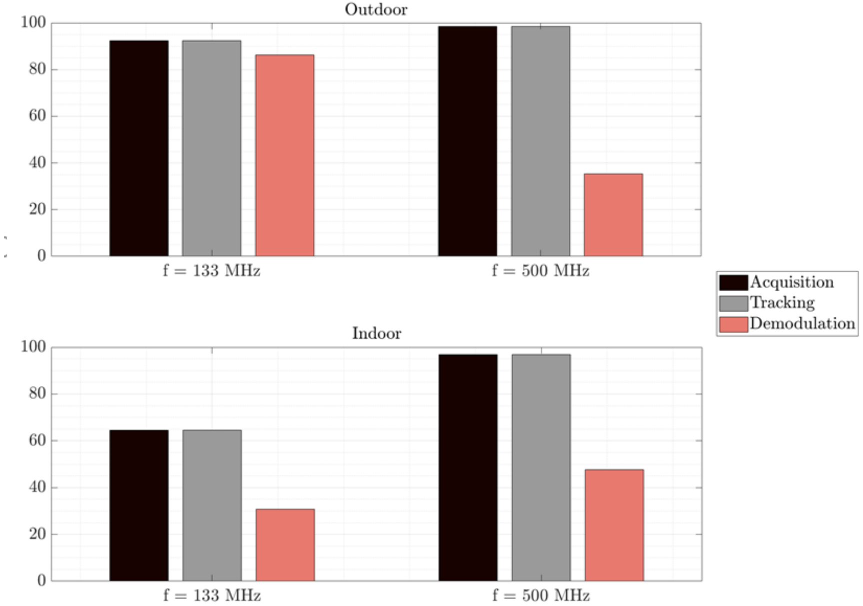
Accomplished work

Real-world experimentation (7/8): LEO pass emulation results

Traditional building



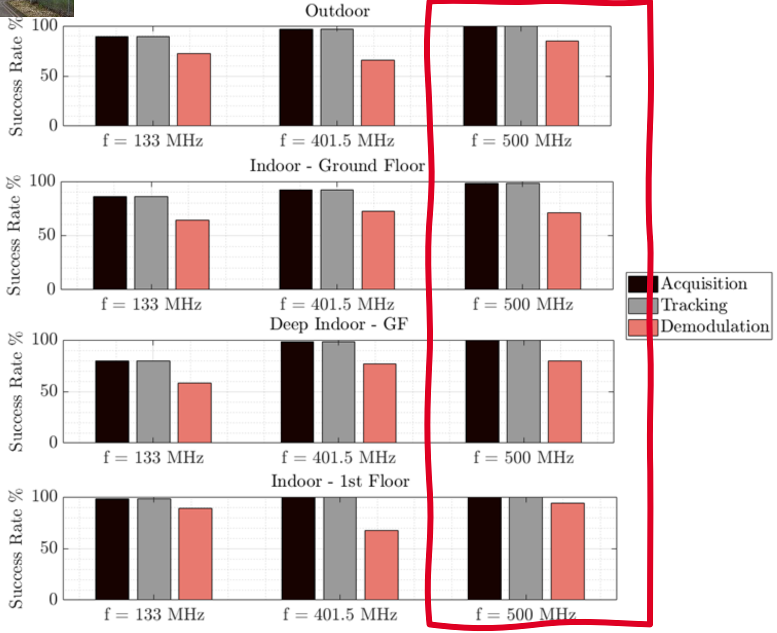
Thermo-efficient building



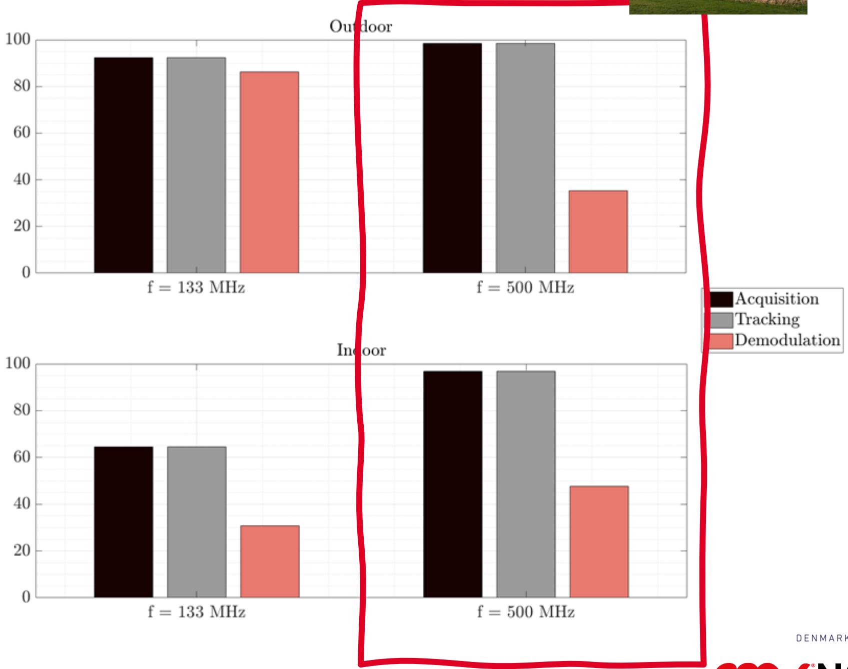
Accomplished work

Real-world experimentation (7/8): LEO pass emulation results

Traditional building

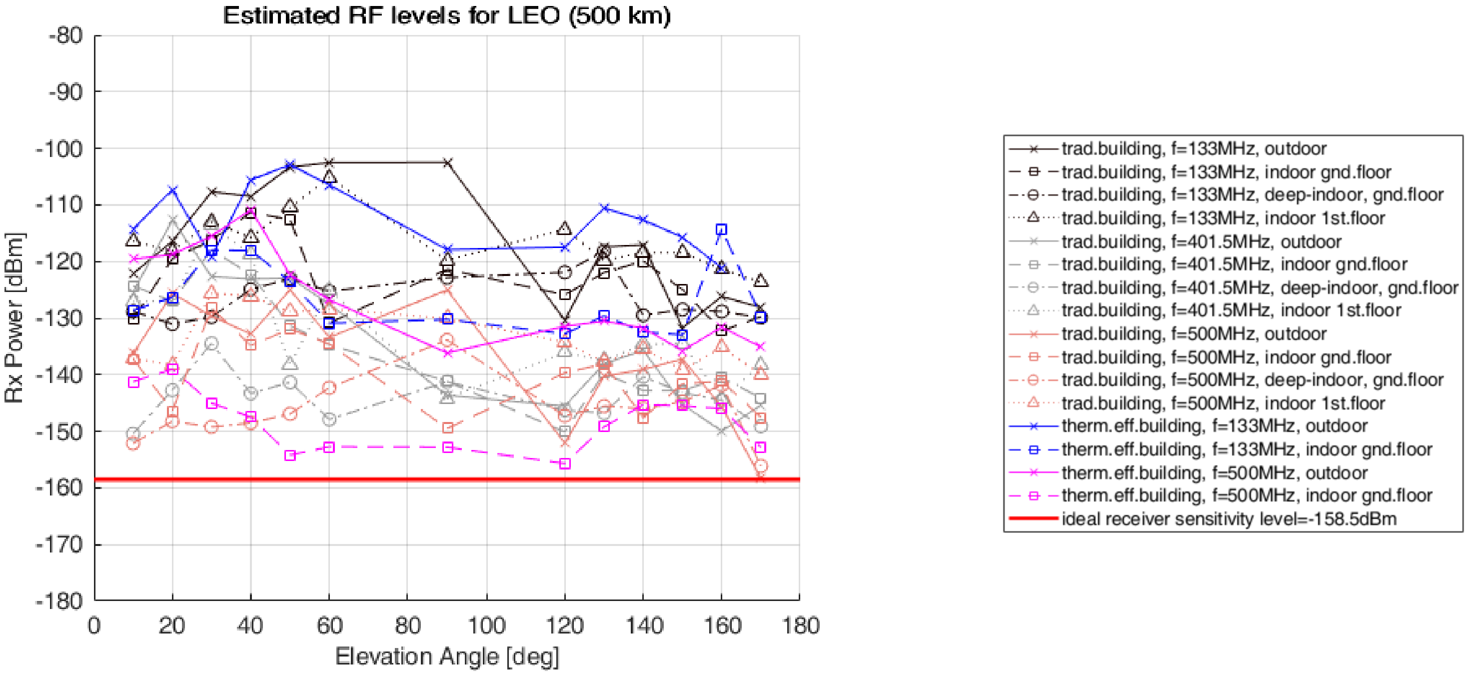


Thermo-efficient building



Accomplished work

Experimentation results (8/8): extrapolation to LEO orbit



Agenda

Project Introduction

Project plan

Work summary

Main conclusions and way forward

Questions and Answers

Main conclusions and way forward

Contract conclusions

- This project shows the **successful first-stage development of a flexible and fast-deployable CARS** based on SDR systems.

- The first stage of the development **demonstrates 133 MHz, 401.5 MHz and 500 MHz provide promising results** in terms of signal propagation and navigation capabilities.
  - **The PoC is based on a single Tx-Rx system** with Spread-Spectrum signals.

- **Experimentation in relevant environments has been carried** out to validate the developed proof-of-concept system.

- Experimentation resembling **LEO satellites geometry** have been carried out in order to verify the validity of the system for the LEO-PNT case.

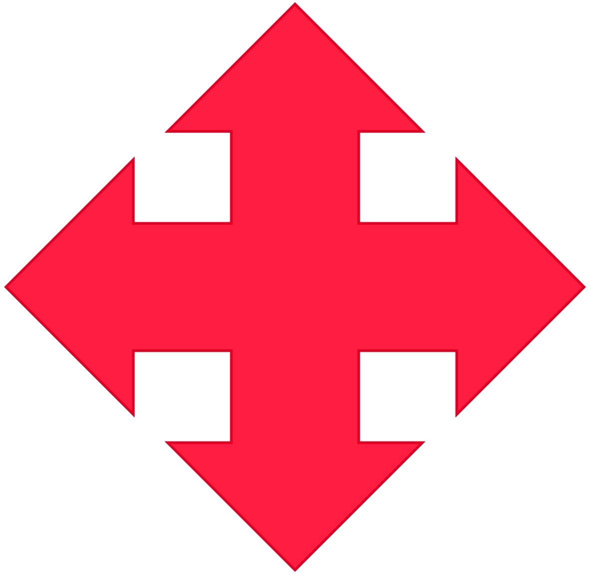
AALBORG UNIVERSITY
DENMARK

gmv NSL

Main conclusions and way forward

What’s next?

Extend analysis to other frequencies
(S band, C band, higher UHF band)



Platform design optimization

Broaden test scenarios and buildings
(including different Tx. platforms)

Analyse other waveforms and signal designs

10/06/2022

Thank you

Low-RF Team

GMV NSL
Alejandro Pérez Conesa, David Payne, David Scott, Wahyudin P. Syam

AAU
Enric Juan Martínez, Ignacio Rodríguez Larrad, Melisa María López Lechuga

AALBORG UNIVERSITY
DENMARK

Q&A