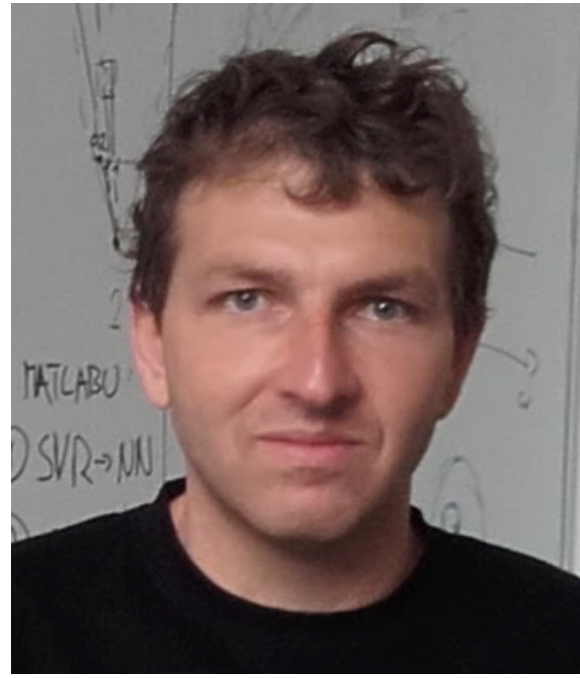


Autonomous robotics: outline

Karel Zimmermann

Outline:

- Who are we and what are we doing?
- What is the Autonomous Robotics course about?
- Course organization



- **Karel Zimmermann**
- ARO lecturer
- associate professor



- **Vojta Vonásek**
- ARO lecturer
- PostDoc researche



🌐 [František Nekovář](#) head of the labs. Exploration path planning lab tutor.



🌐 [Robert Pěnička](#) ROS tutor.



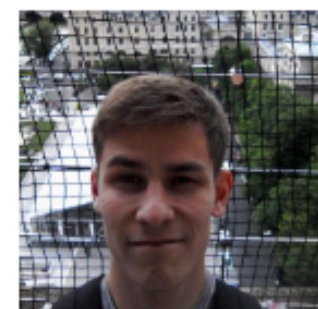
🌐 [Vít Krátký](#) is the exploration and path following lab tutor.



✉ [Bedřich Himmel](#) is technical support staff



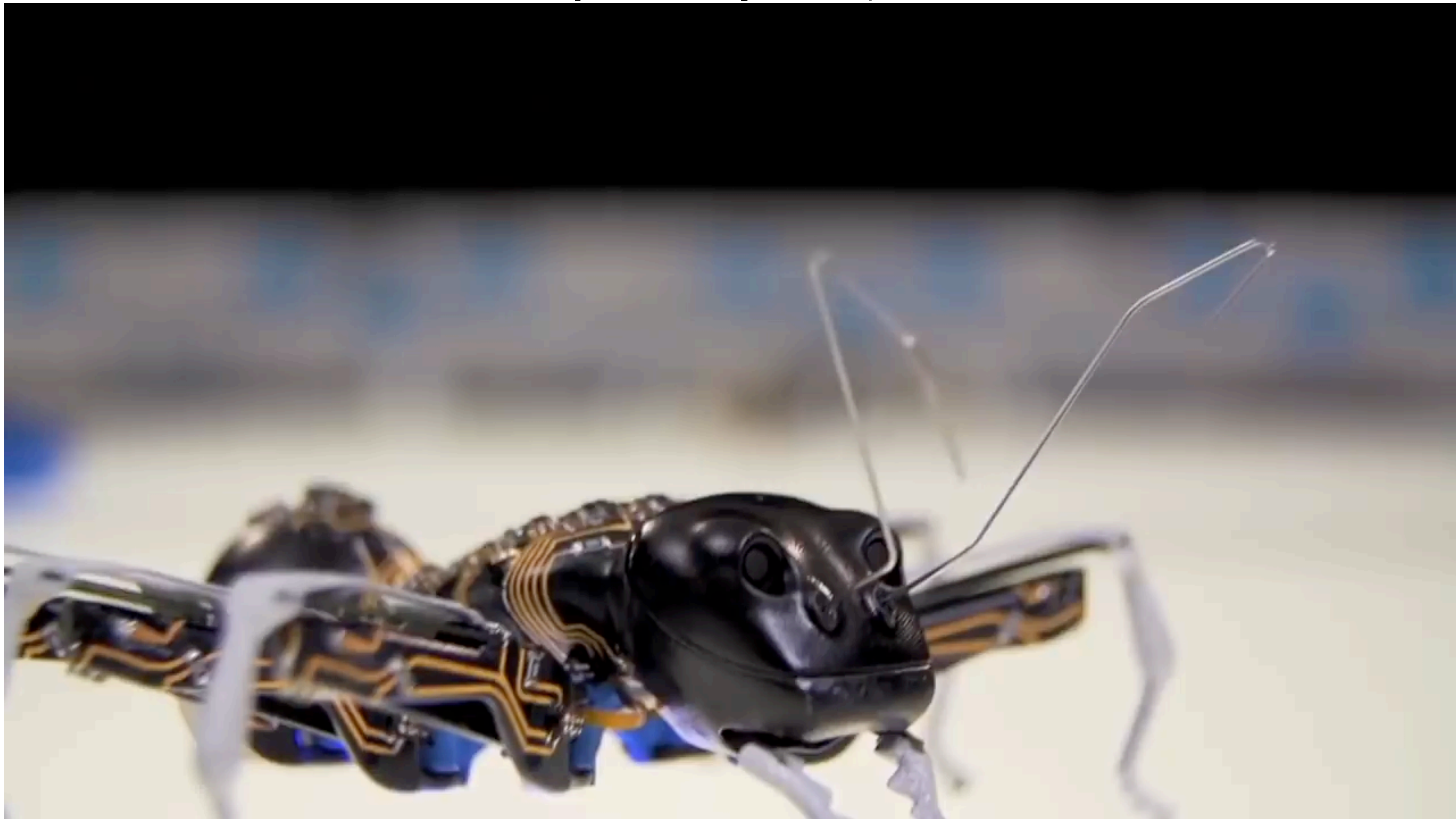
🌐 [Martin Pecka](#) is localization labs tutor and can help with ROS-related questions.



✉ [Ruslan Agishev](#) is ICP SLAM lab tutor

Robotics == do some **super-fancy** or **super-useful** stuff with robots

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Robotics == do some super-fancy or **super-useful** stuff with robots



Outline:

- Who are we and what are we doing?
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We do what DARPA thinks to be robotics

DARPA (Defense Advanced Research Projects Company)
budget \$3.528 billion/year

GOAL of DARPA robotic challenges:
Develop ground robotic capabilities to execute complex tasks in a priori
unknown, uncontrolled environments.

DARPA Grand Challenge 2004, 2005



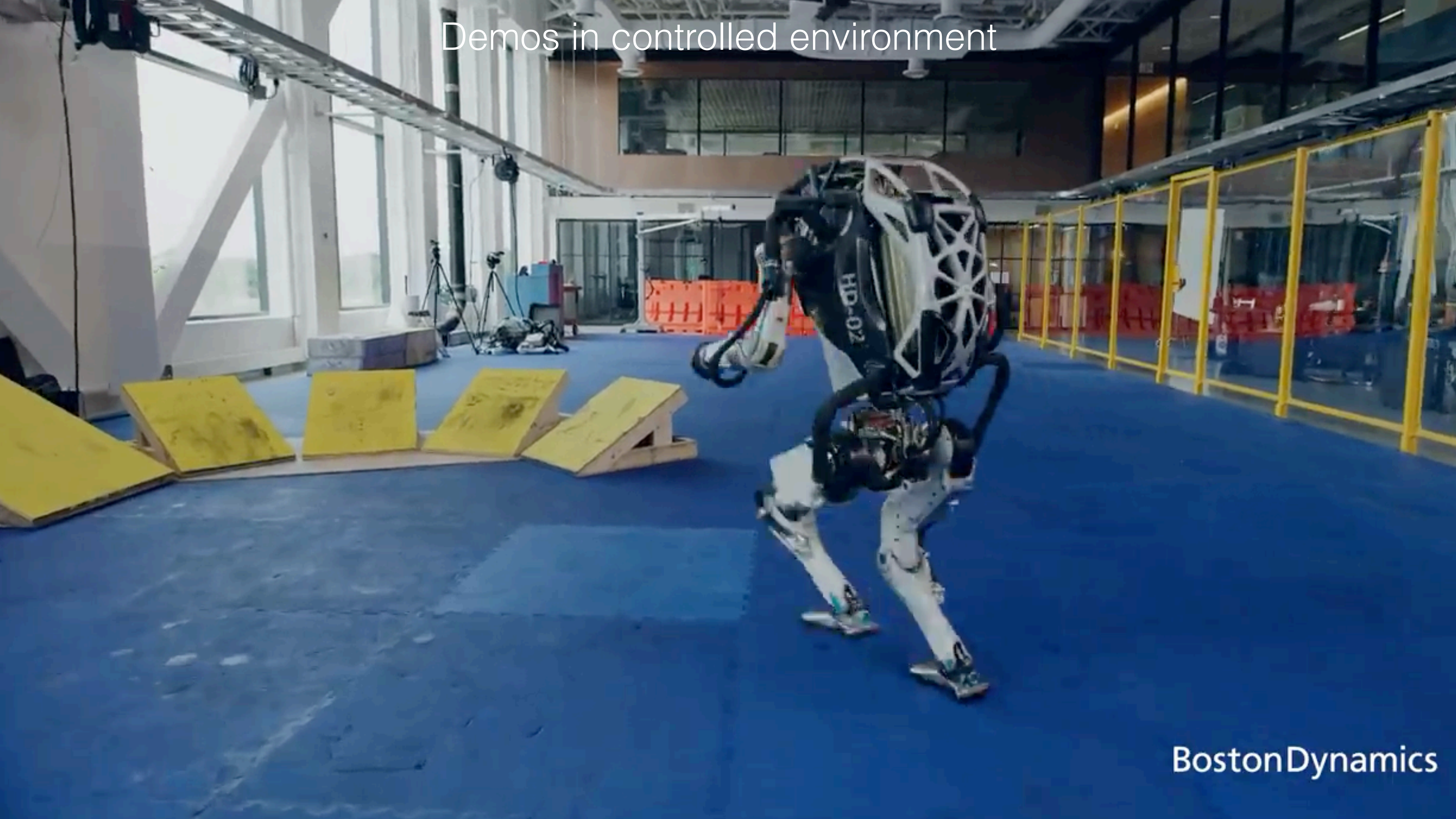
DARPA Urban Challenge 2007



DARPA Robotics (humanoid) challenge
2012-2015



Demos in controlled environment



Boston Dynamics

DARPA Robotics (humanoid) challenge
2012-2015



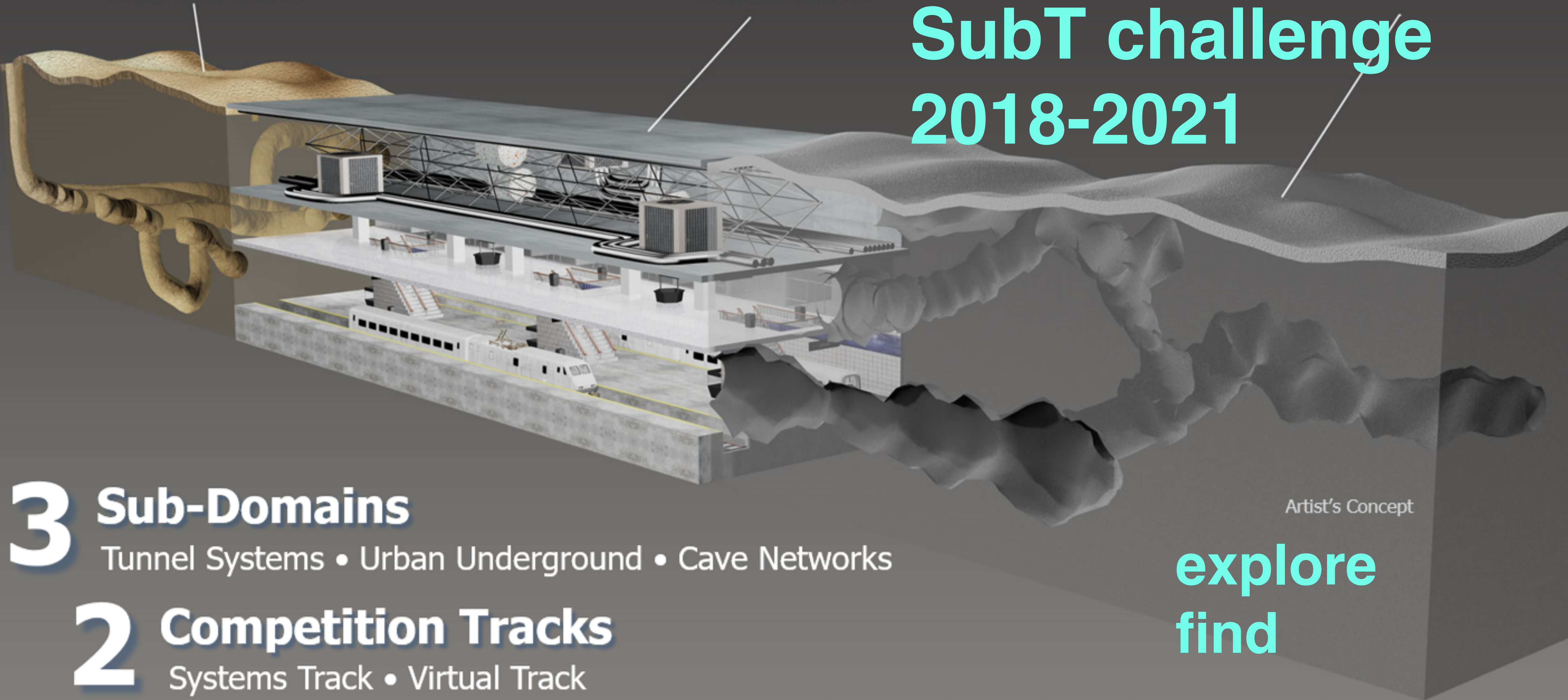
6:16:34 05/06/2015

Tunnel Environment

Urban Environment

Cave Environment

SubT challenge 2018-2021



3 Sub-Domains

Tunnel Systems • Urban Underground • Cave Networks

2 Competition Tracks

Systems Track • Virtual Track

1 Revolutionary Vision

Create breakthrough technologies and capabilities for underground operations

Artist's Concept

explore
find

Learn More at
www.darpa.mil





CTU

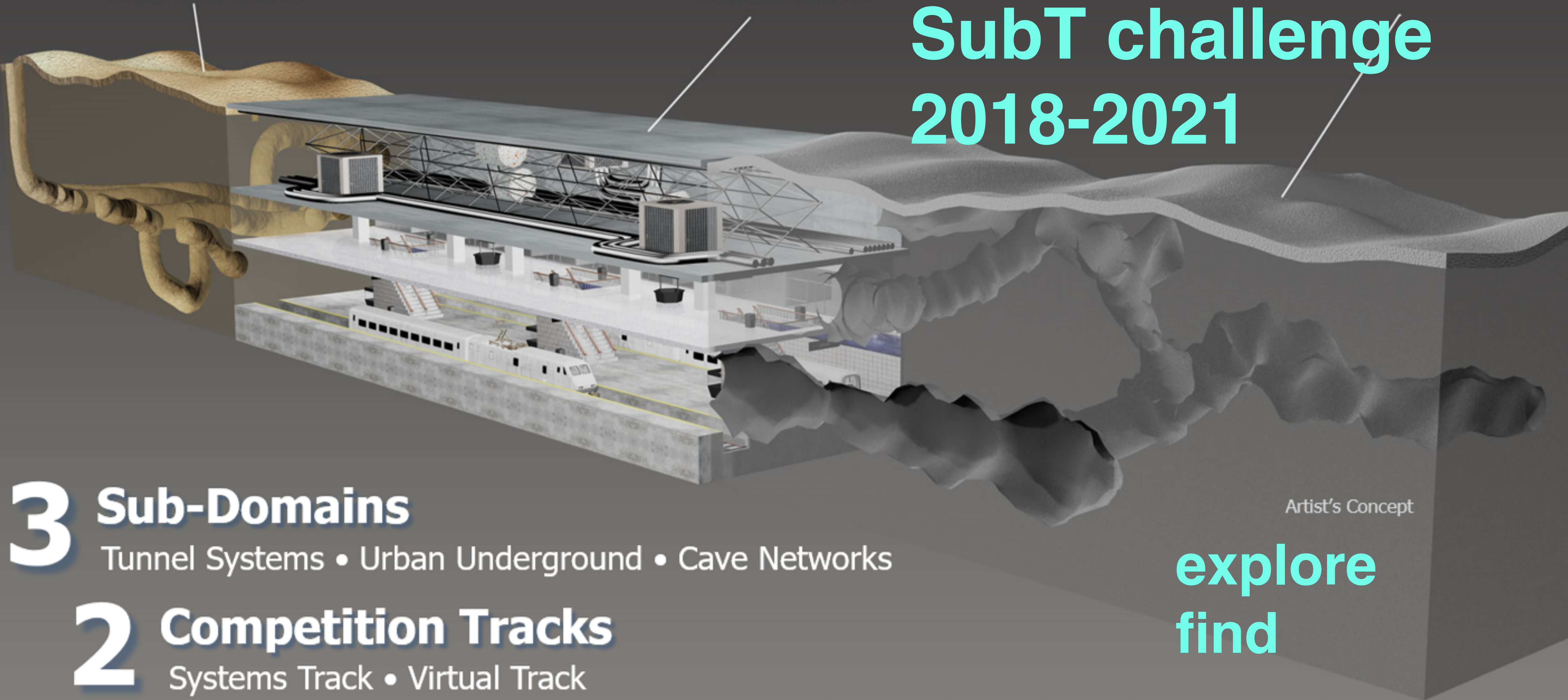


Tunnel Environment

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Time: T-45 mins



Time: T-35 mins



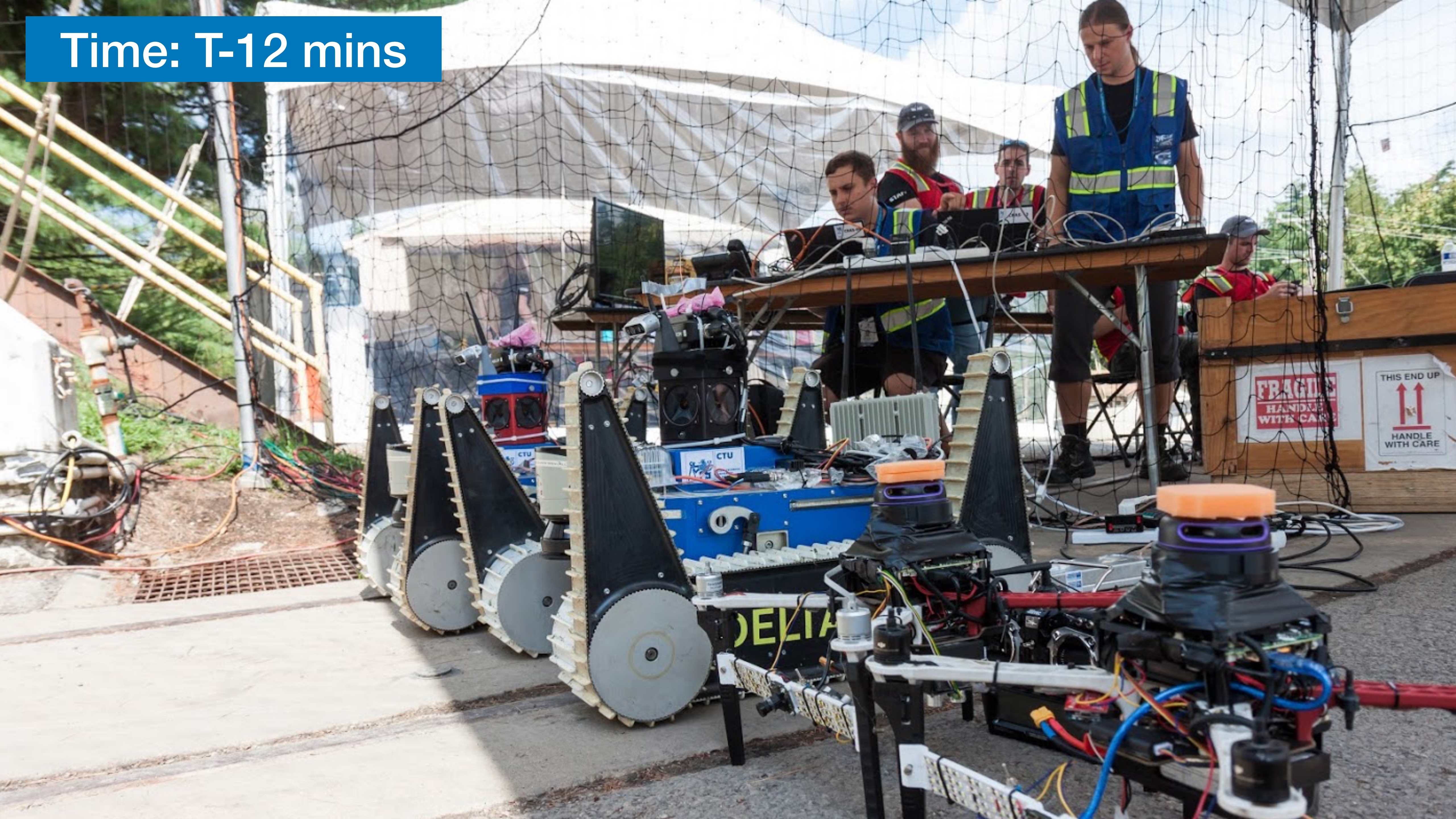
Time: T-30 mins



Time: T-15 mins



Time: T-12 mins



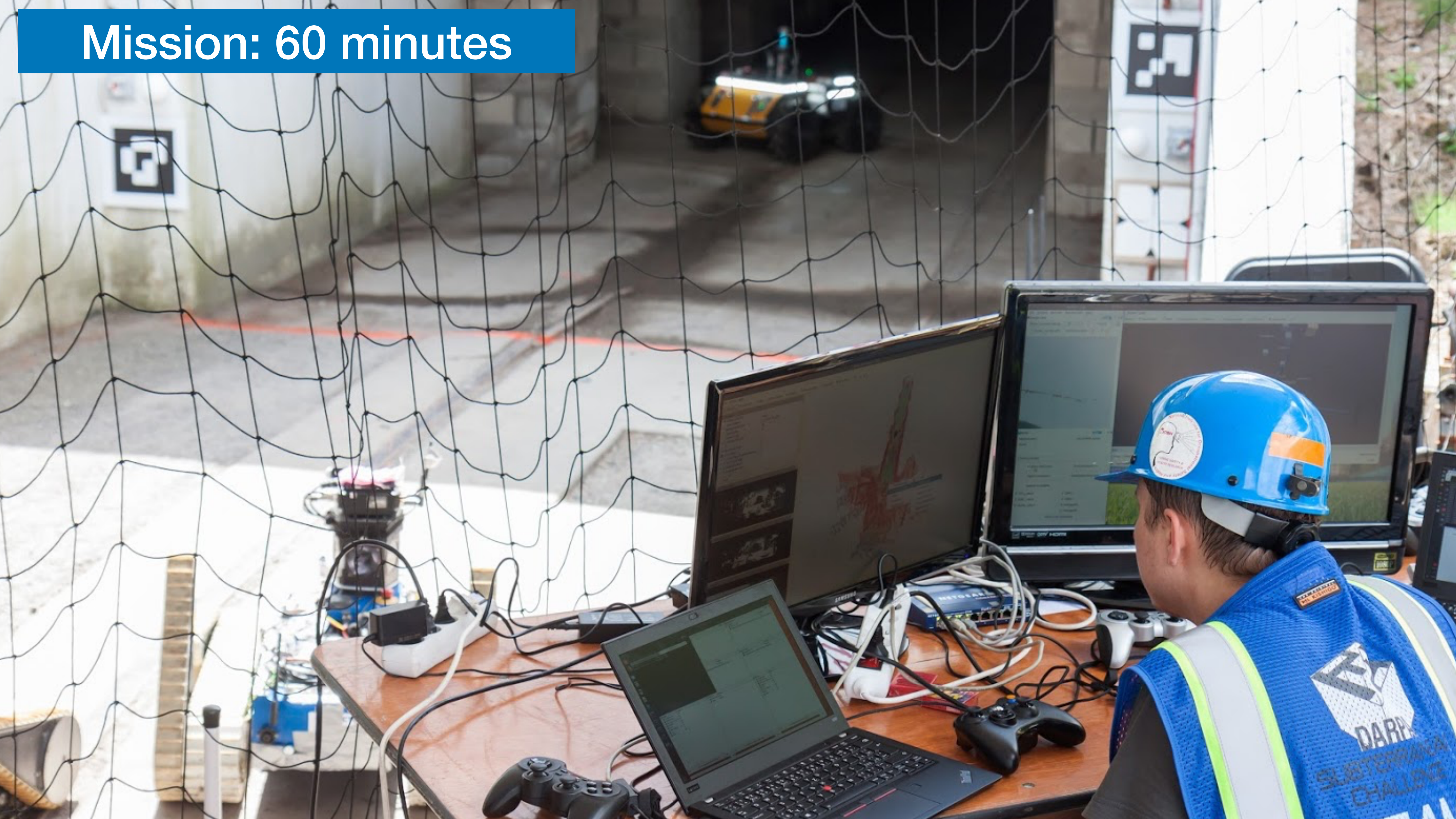
Time: T-05 mins



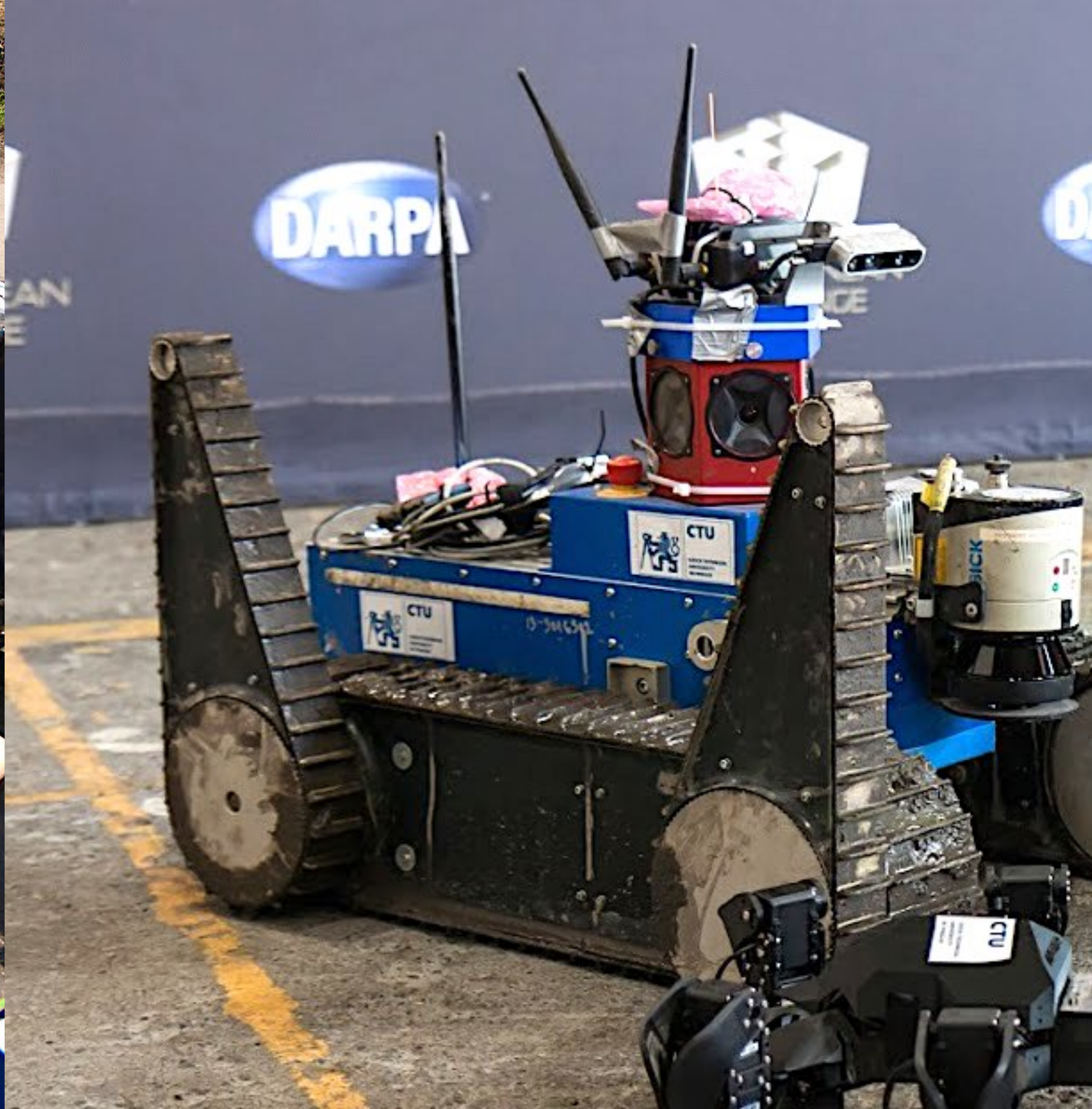
Mission: 60 minutes



Mission: 60 minutes



Time: $T > 60$ mins

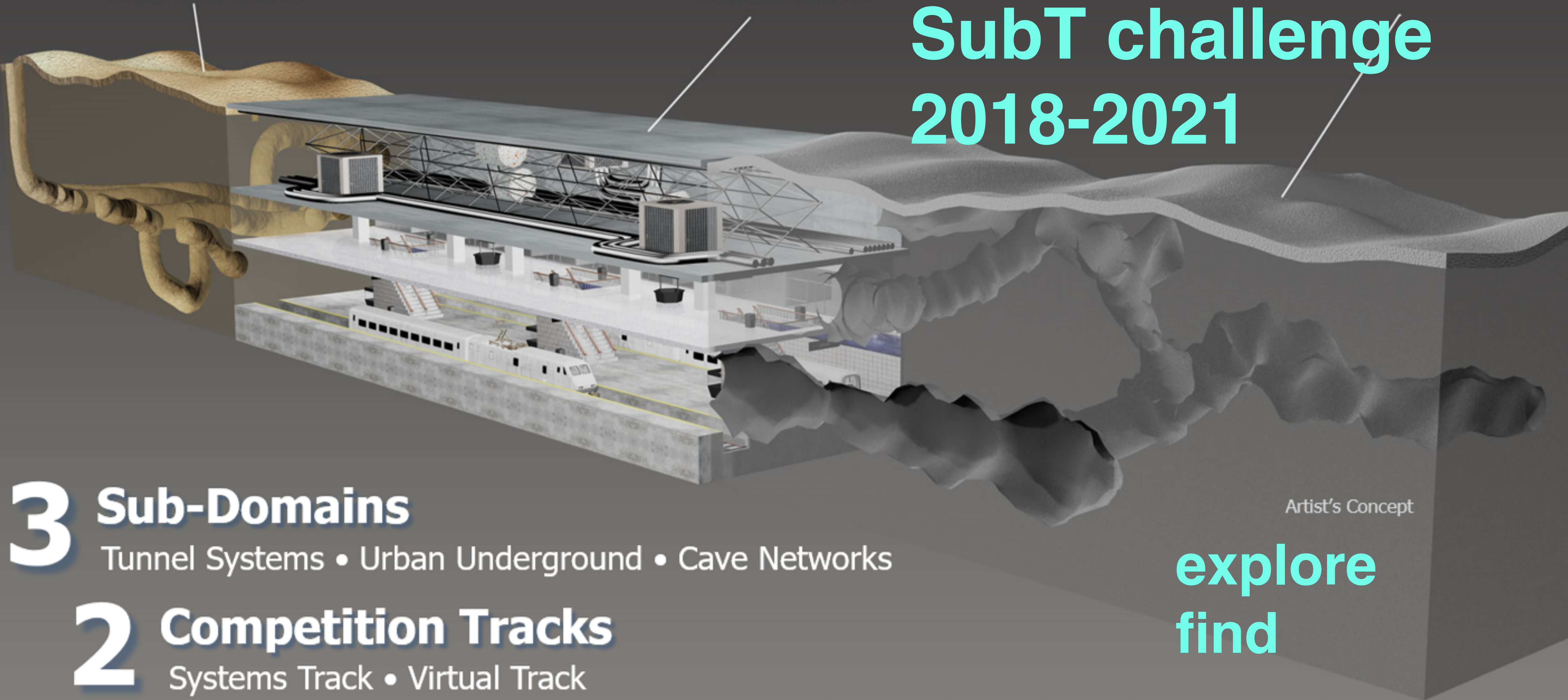


Tunnel Environment

Urban Environment

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SubT challenge 2018-2021



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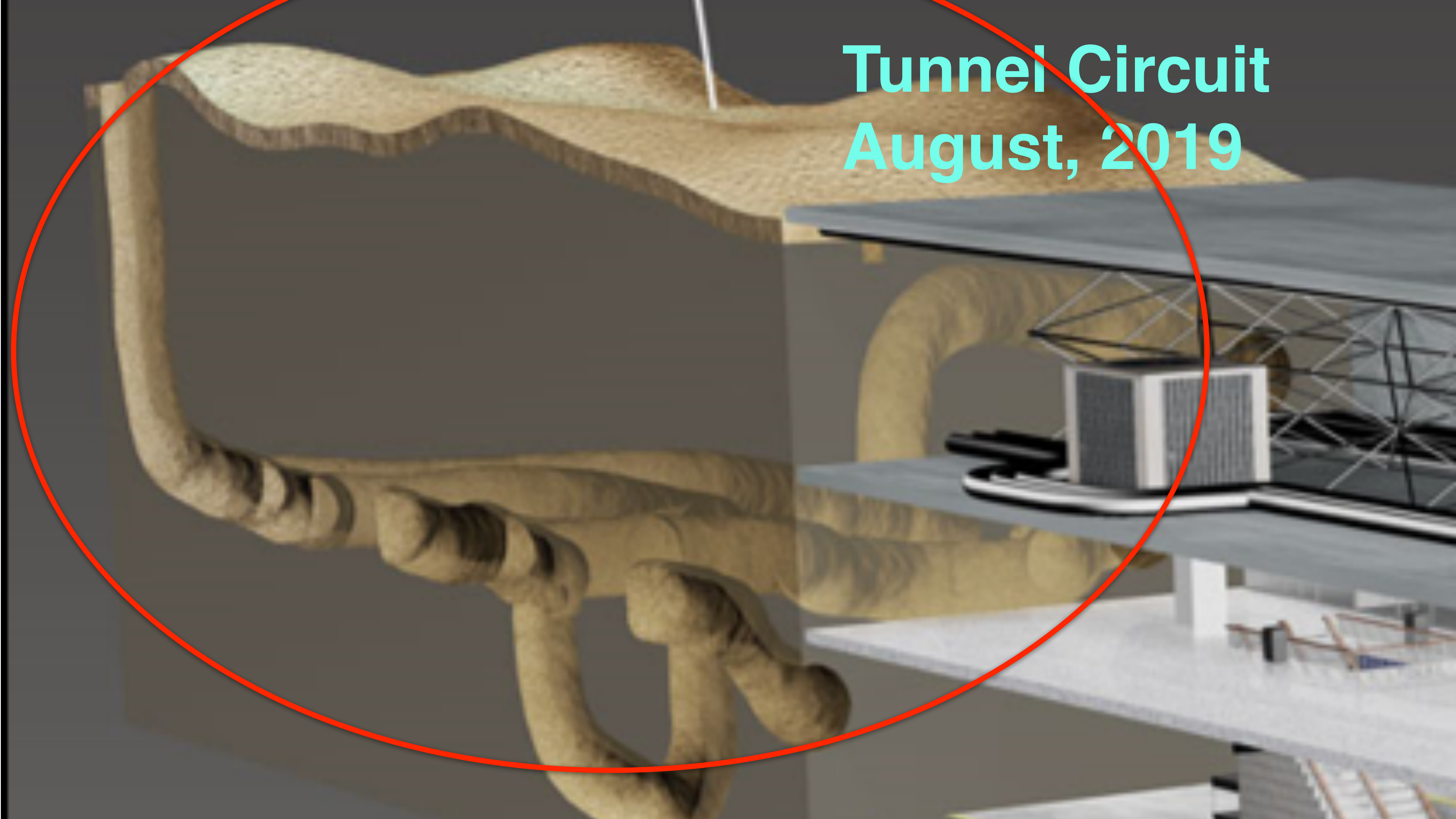
Create breakthrough technologies and capabilities for underground operations

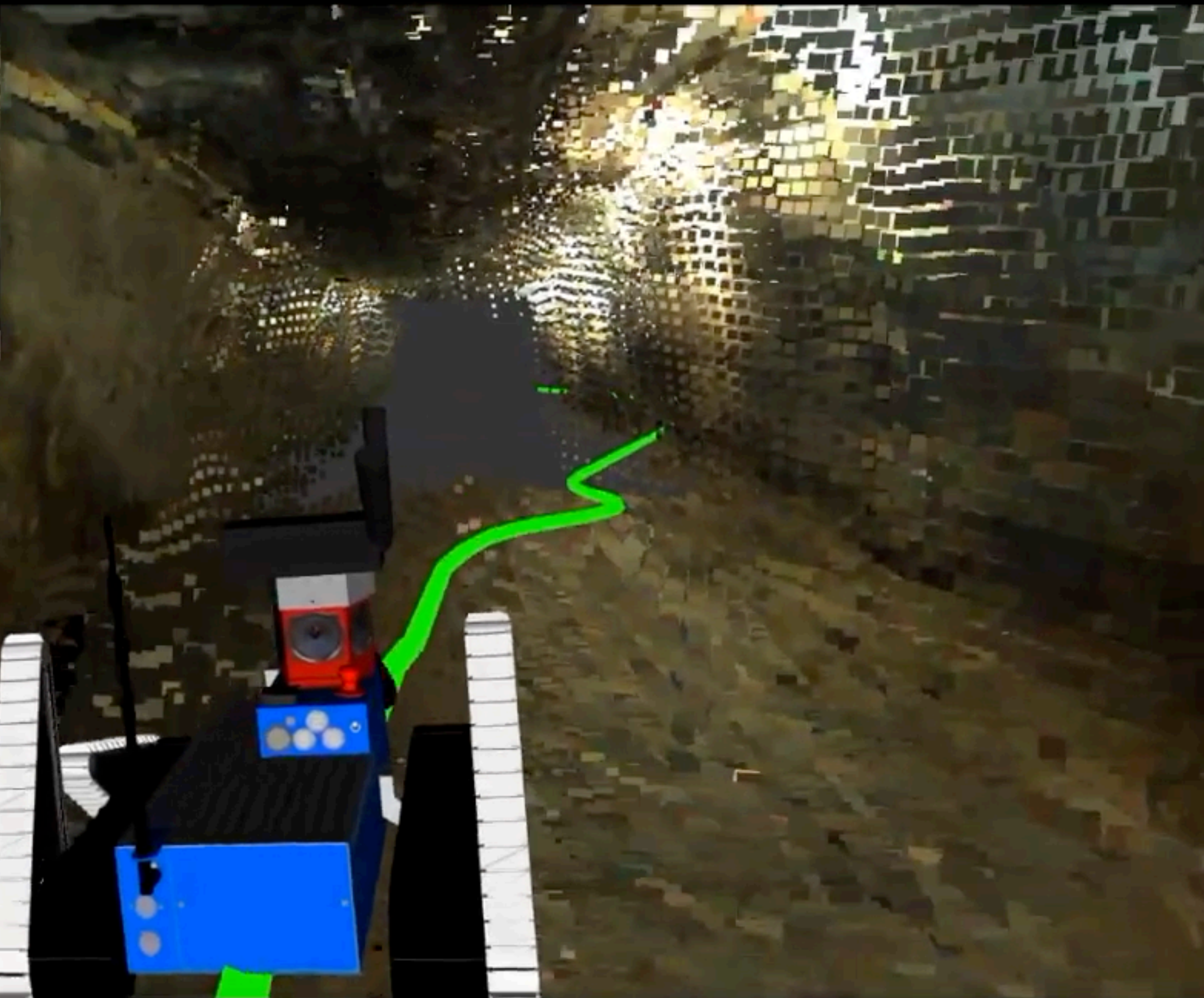
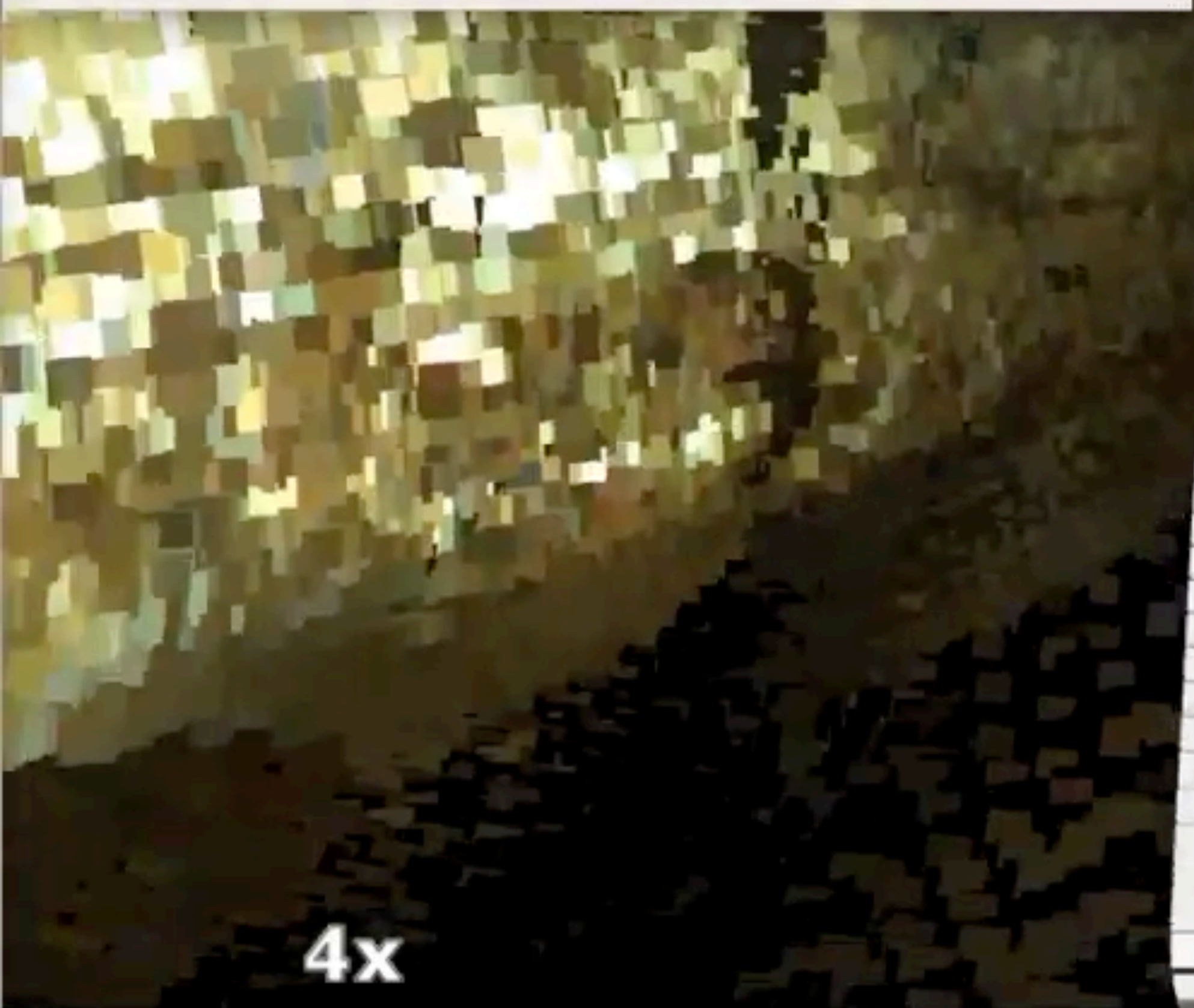
explore
find

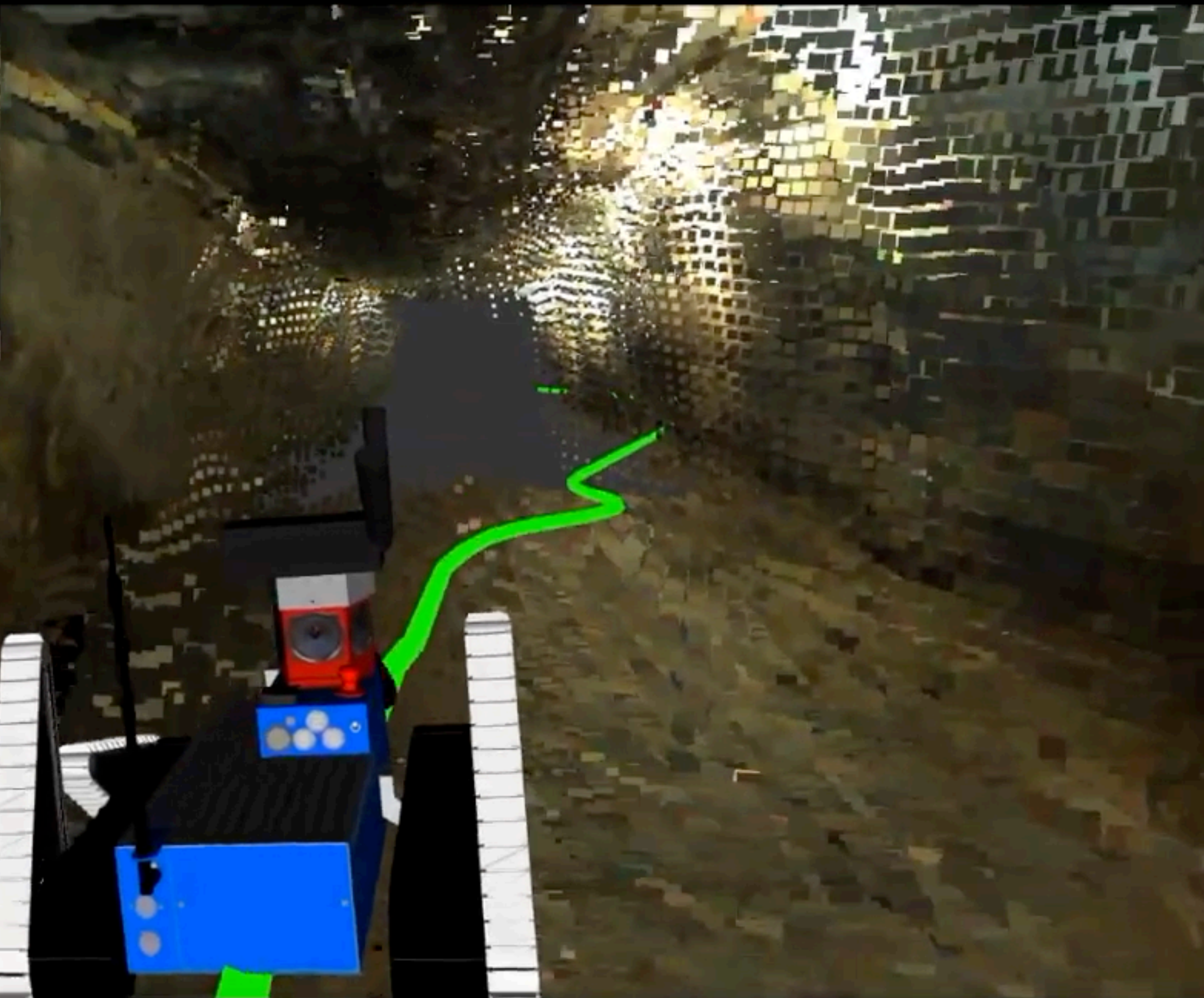
Learn More at
www.darpa.mil

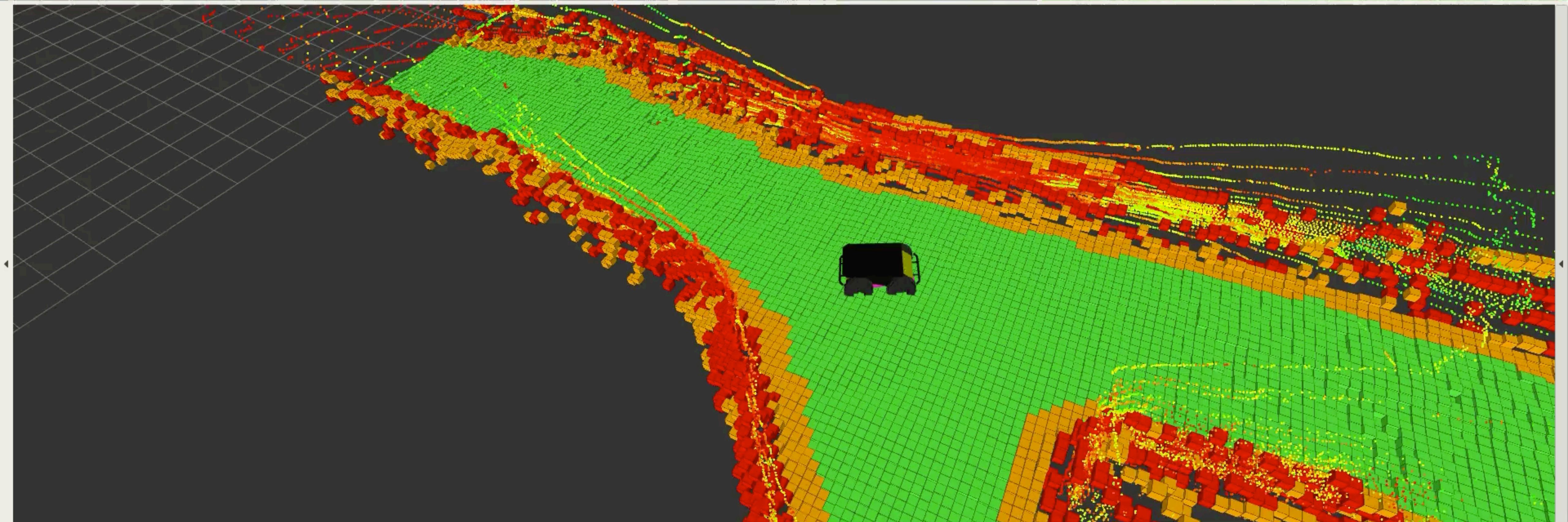
Tunnel Circuit

August, 2019





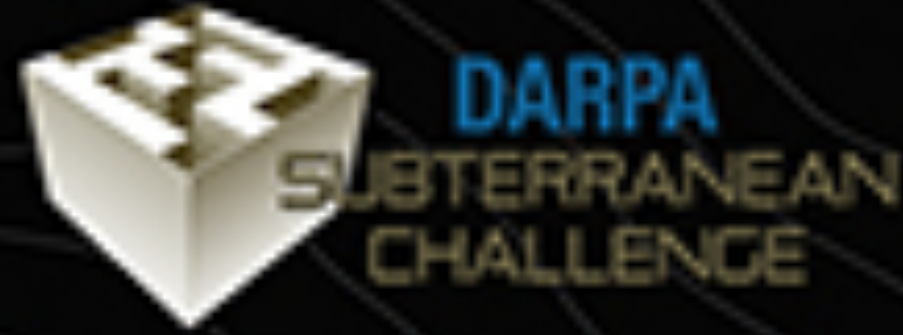




Reset

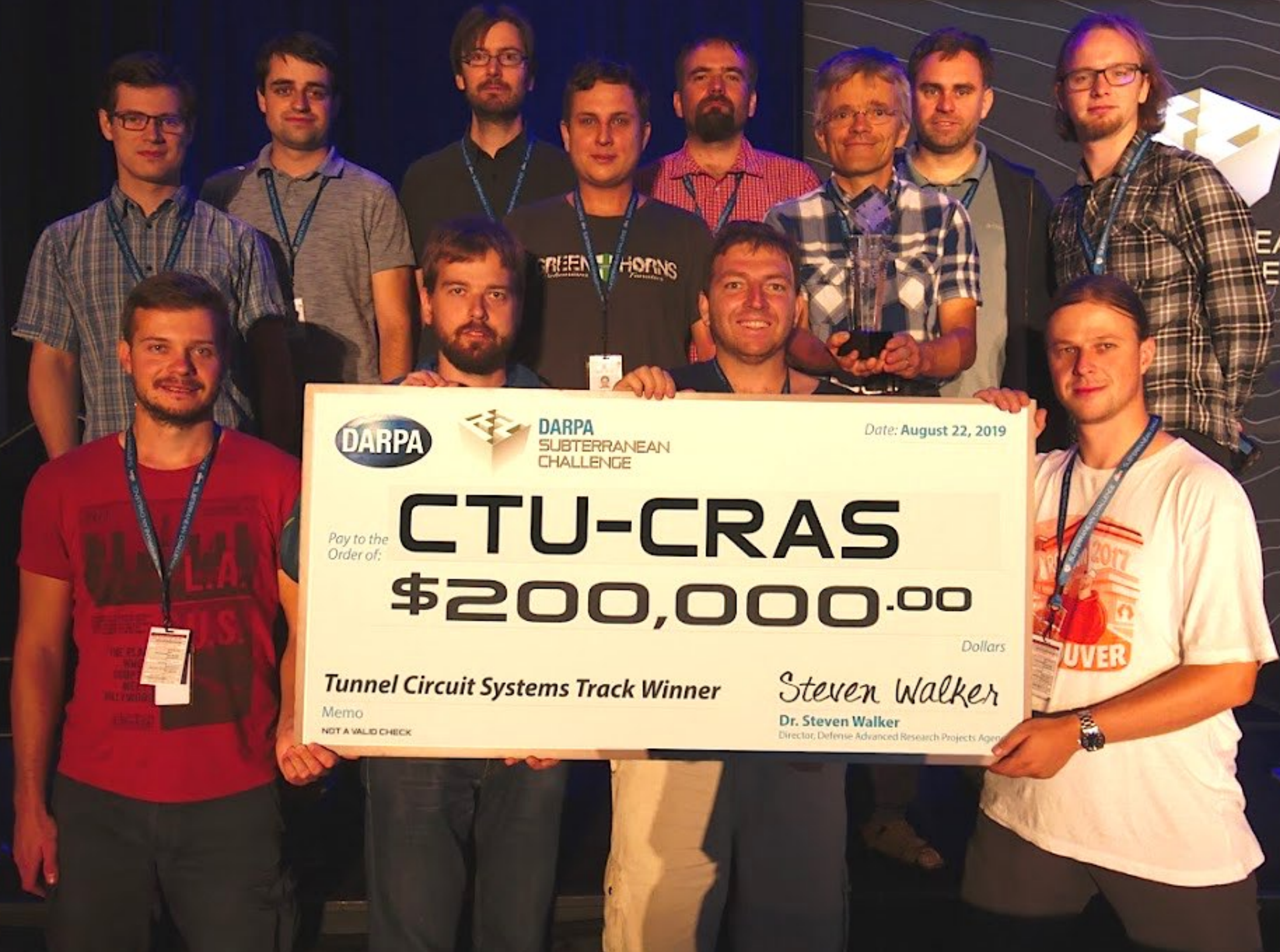
30 fps

All of the Winners in the DARPA SubT Tunnel Circuit



LEADERBOARD

TEAM	CURRENT SCORE	SR1	SR2	EX1	EX2
Explorer	25	13	12	10	12
CoSTAR	11	4	7	2	4
CTU-CRAS	10	1	5	5	5
MARBLE	9	2	2	7	6
CSIRO Data61	7	2	3	2	4
CERBERUS	5	1	4	1	0
NCTU	2	0	0	0	2
Robotika	2	1	0	1	1
CRETISE	1	1	1	0	0
PLUTO	1	1	1	0	0
Coordinated Robotics	0	0	0	0	0



DARPA  **DARPA SUBTERRANEAN CHALLENGE** Date: August 22, 2019

Pay to the Order of: **CTU-CRAS**

\$200,000.00 Dollars

Tunnel Circuit Systems Track Winner *Steven Walker*

Memo **Dr. Steven Walker**

NOT A VALID CHECK Director, Defense Advanced Research Projects Agency

GREEN HORNS

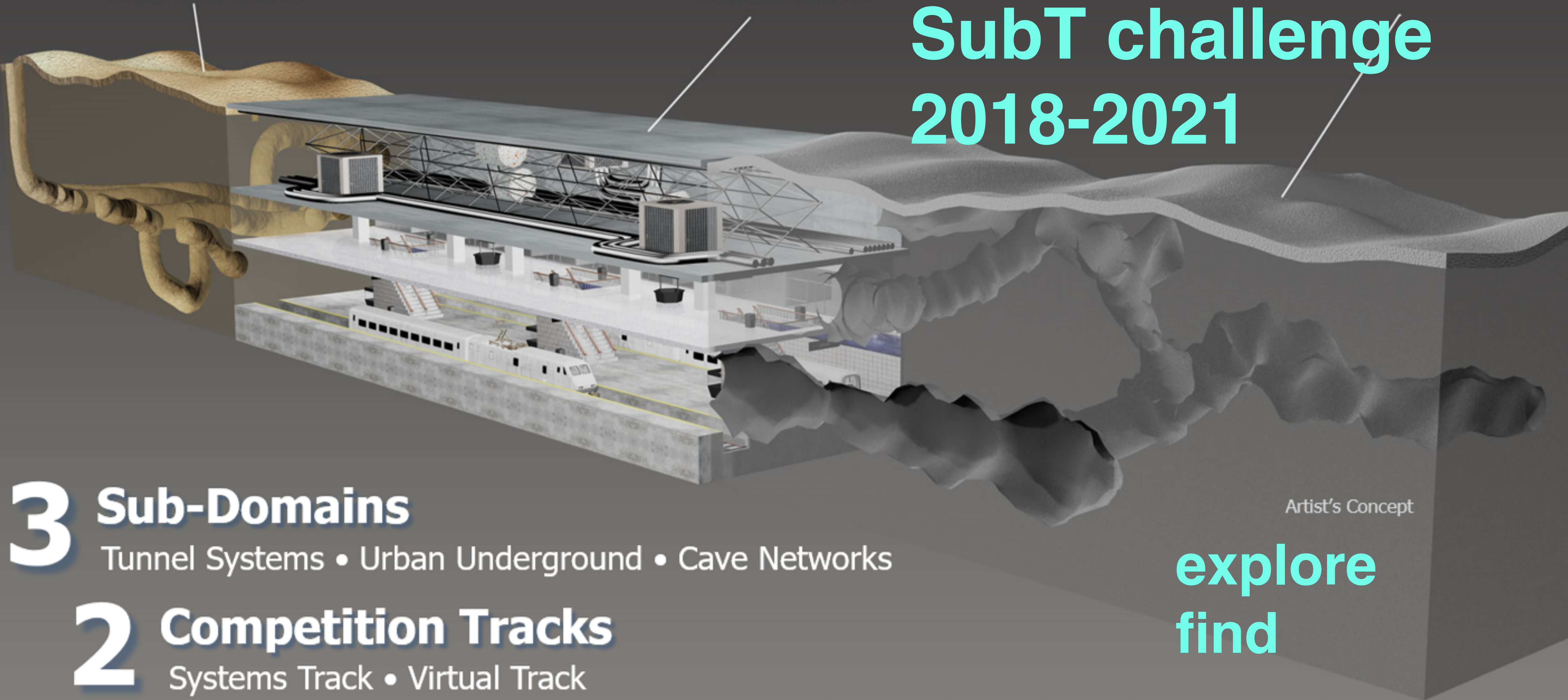
2017
OVER

Tunnel Environment

Urban Environment

Cave Environment

SubT challenge 2018-2021



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Tunnel Systems • Urban Underground • Cave Networks

2 Competition Tracks

Systems Track • Virtual Track

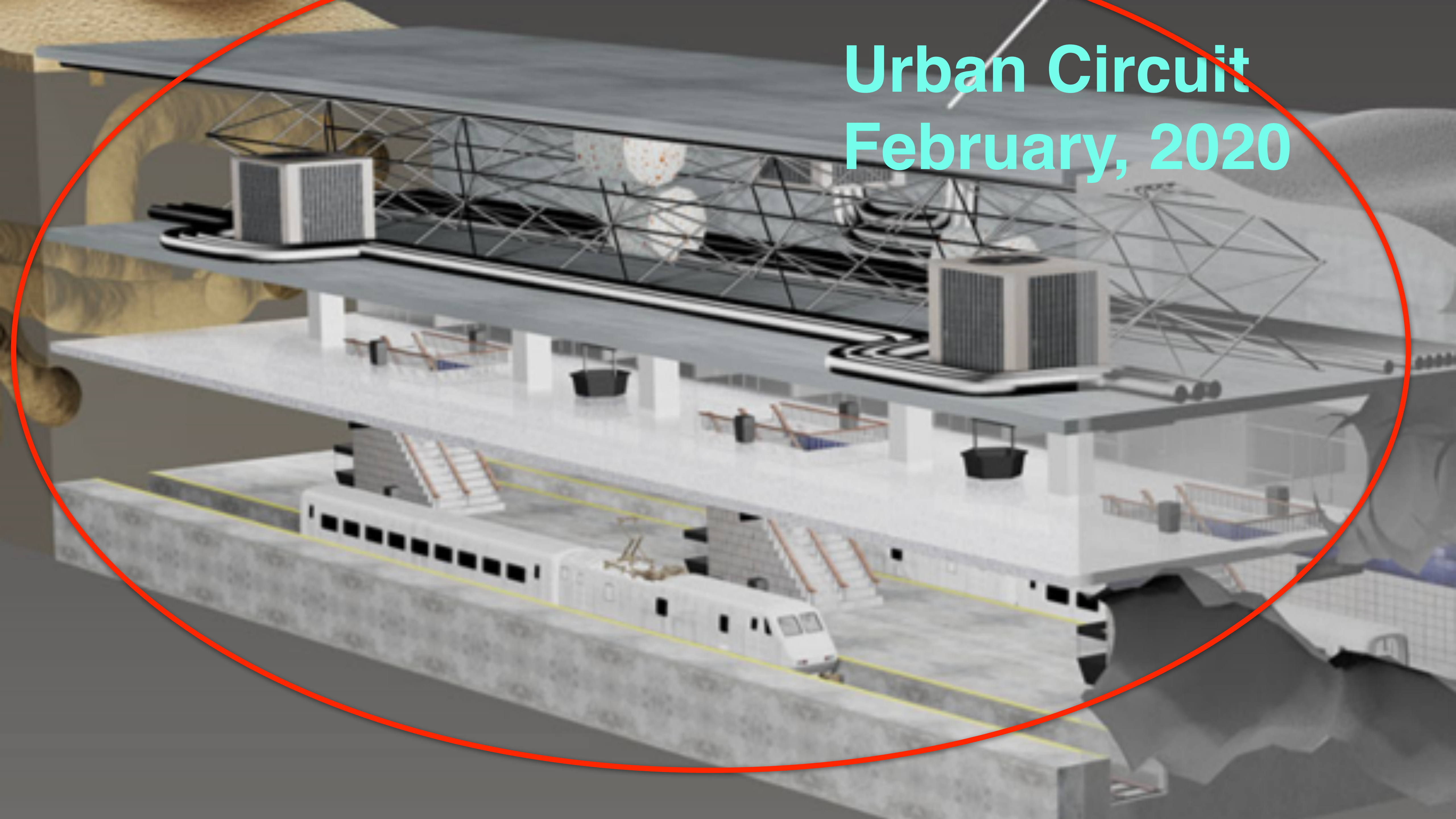
1 Revolutionary Vision

Create breakthrough technologies and capabilities for underground operations

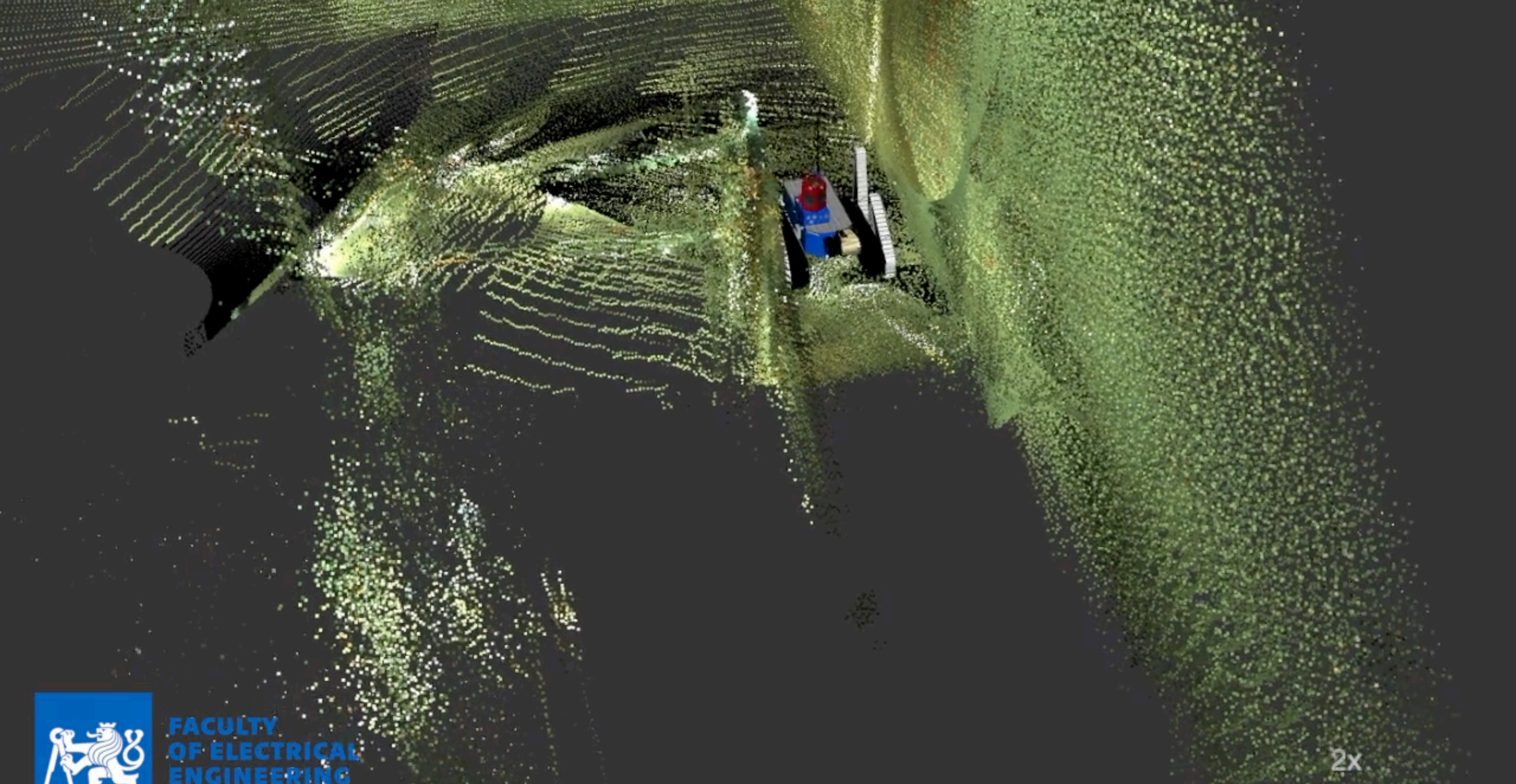
explore
find

Learn More at
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Urban Circuit February, 2020







FACULTY
OF ELECTRICAL
ENGINEERING
CTU IN PRAGUE

2x

DARPA SubTerraanean Challenge - Urban Circuit, 2020/02

LEADERBOARD

URBAN CIRCUIT



DARPA
SUBTERRANEAN
CHALLENGE

Team	Alpha 1	Alpha 2	Beta 1	Beta 2	Score
CoSTAR	5	7	4	9	16
Explorer	6	4	5	5	11
CTU-CRAS-NORLAB	4	6	3	4	10
CSIRO Data61	3	4	3	5	9
CERBERUS	4	1	3	3	7
Coordinated Robotics	1	3	1	1	4
MARBLE	1	1	3	3	4
NCTU	1	0	1	0	2
Robotika	1	1	1	1	2
NUS SEDS	0	0	1	1	1



DARPA
SUBTERRANEAN
CHALLENGE

DARPA
SUBTERRANEAN
CHALLENGE

DARPA
SUBTERRANEAN
CHALLENGE

DARPA SUBTERRANEAN CHALLENGE Date: February 27, 2020
Pay to the Order of: **CTU-CRAS-NORLAB**
\$500,000.00 Dollars
Urban Circuit Systems Competition Winner *Peter Highnam*
Memo: Dr. Peter Highnam
NOT A VALID CHECK Acting Director, Defense Advanced Research Projects Agency

Tunnel Environment

Urban Environment

Cave Environment

SubT challenge 2018-2021

3 Sub-Domains

Tunnel Systems • Urban Underground • Cave Networks

2 Competition Tracks

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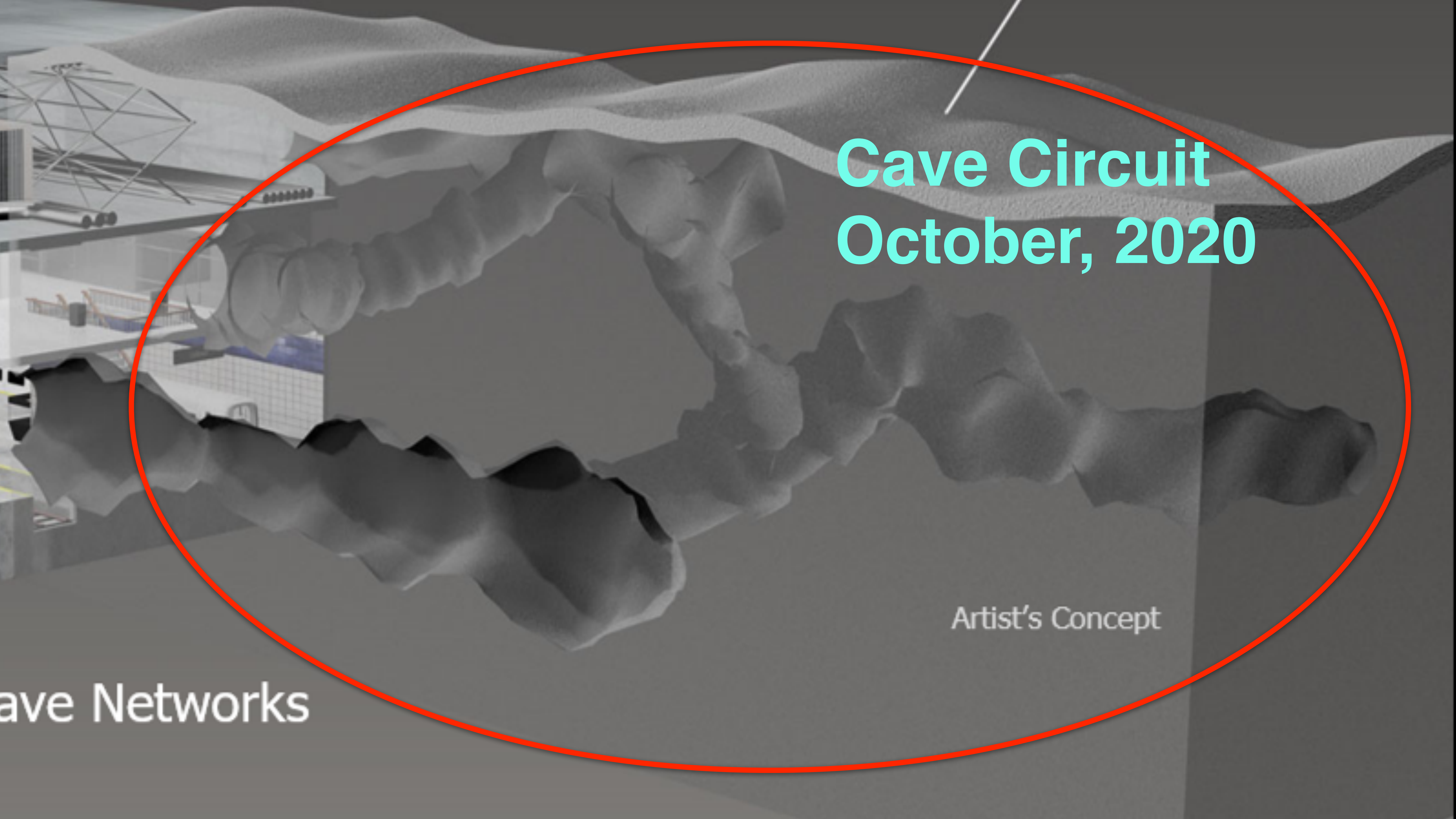
1 Revolutionary Vision

Create breakthrough technologies and capabilities for underground operations

Artist's Concept

explore
find

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Cave Circuit October, 2020

Artist's Concept

Cave Networks



**Final event
September, 2021**

3 Sub-Domains

Tunnel Systems • Urban Underground • Cave Networks

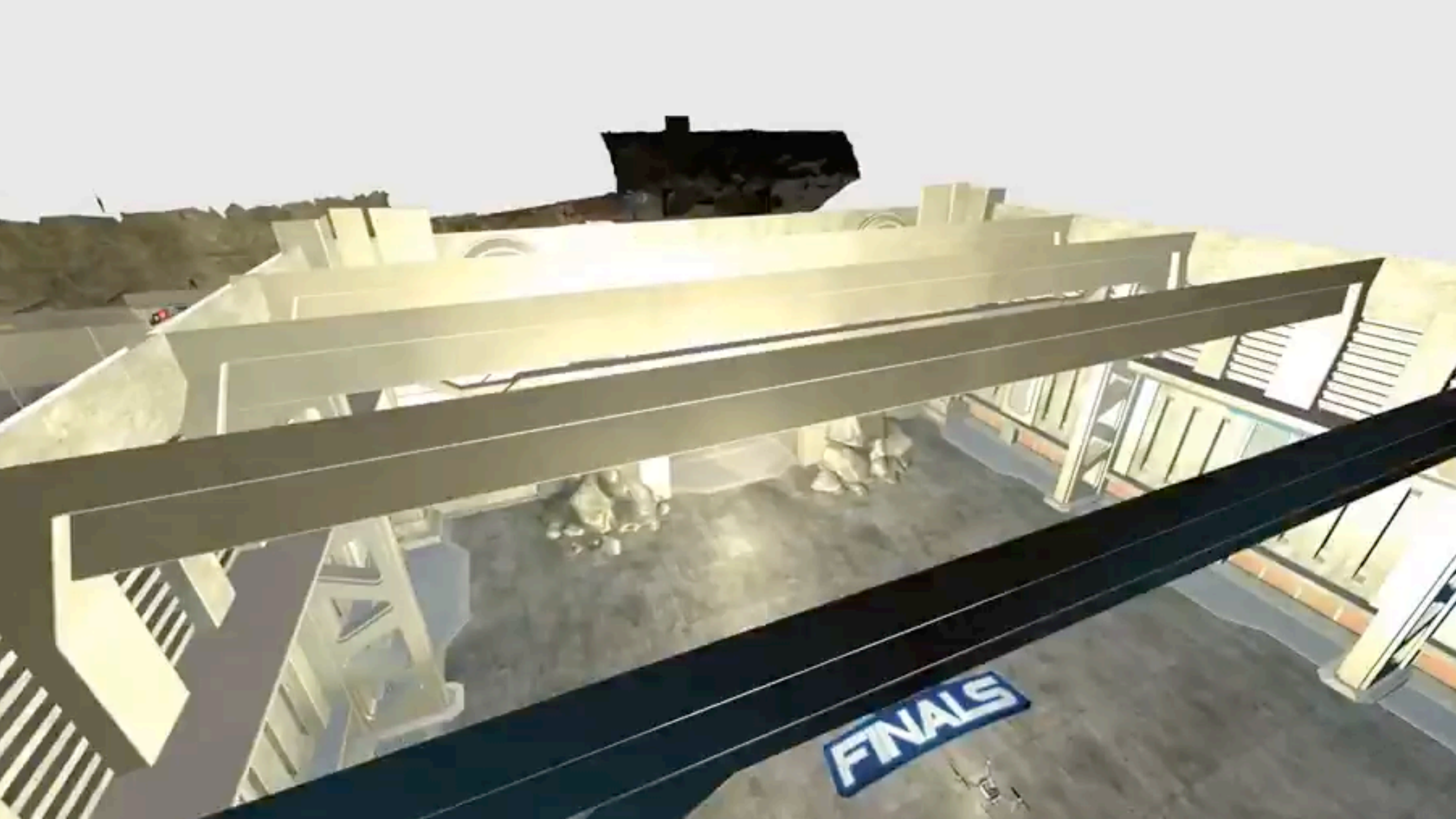
2 Competition Tracks

Systems Track • Virtual Track

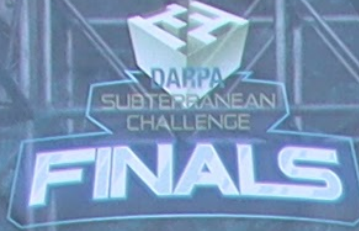
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Create breakthrough technologies and capabilities for underground operations

**Learn More at
www.darpa.mil**

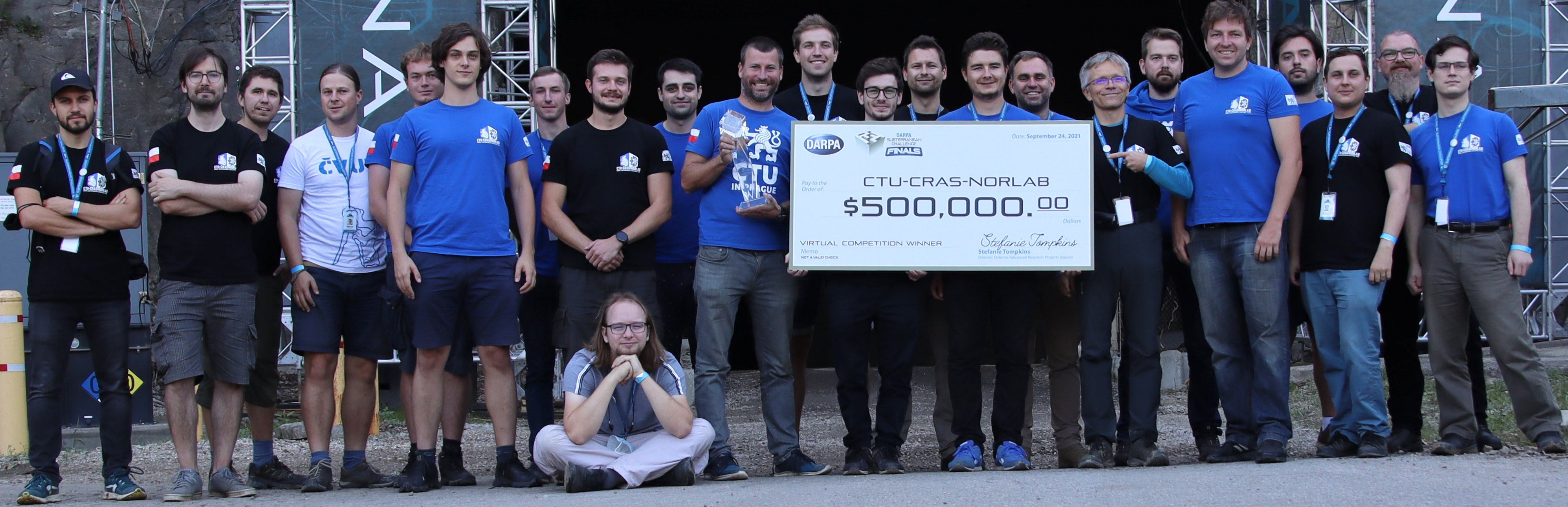


DARPA SUBTERRANEAN CHALLENGE



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DARPA SUBTERRANEAN CHALLENGE FINALS

Date: September 24, 2021

Pay to the Order of: **CTU-CRAS-NORLAB**

\$500,000.00 Dollars

VIRTUAL COMPETITION WINNER

Stefanie Tompkins
Stefanie Tompkins
Director, Defense Advanced Research Projects Agency

MEMO: NOT A VALID CHECK



Outline:

- Who are we and what are we doing?
- What is the Autonomous Robotics course about?
- Course organization

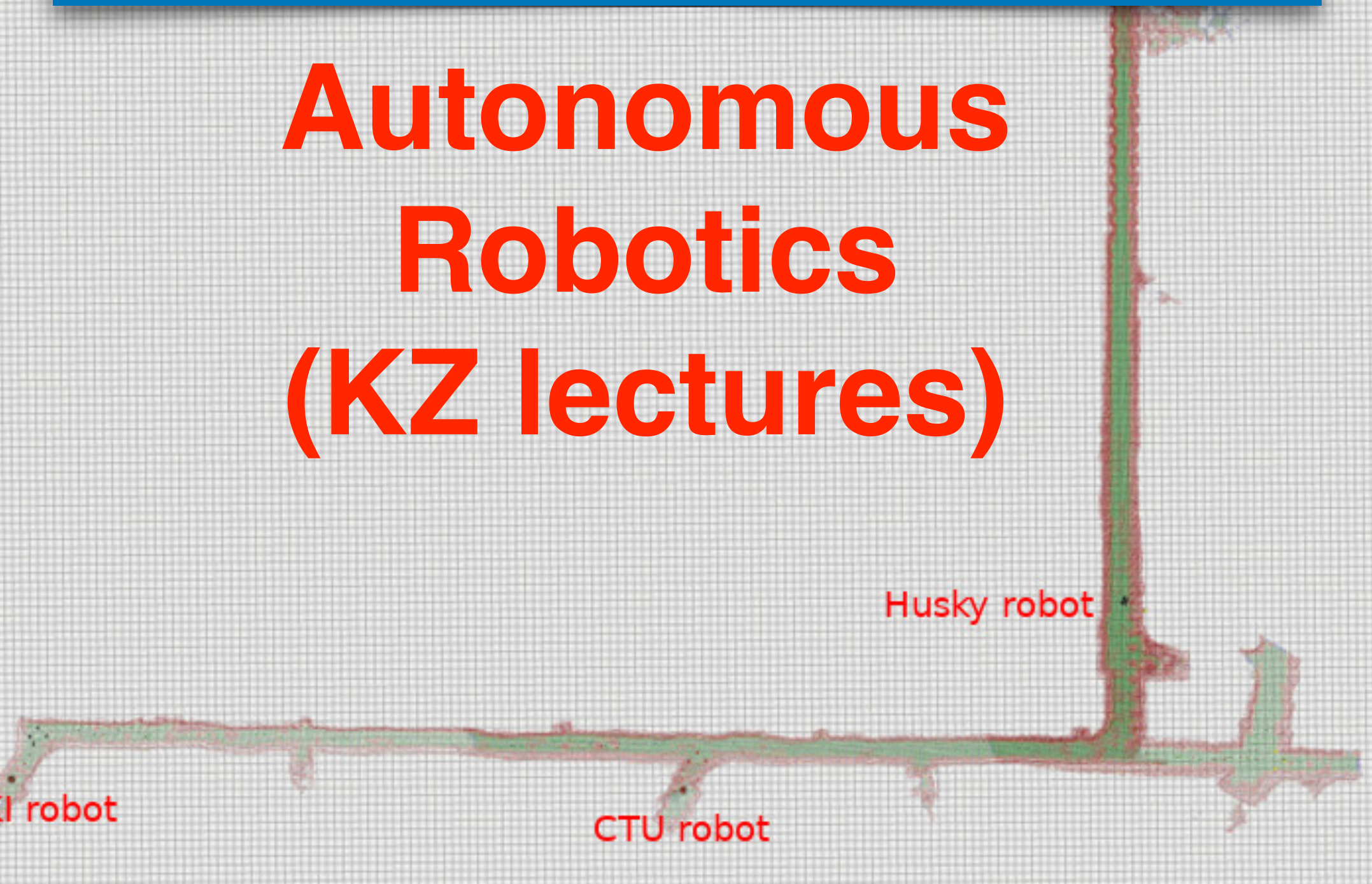
Autonomous robotics course

=

“How we do it”

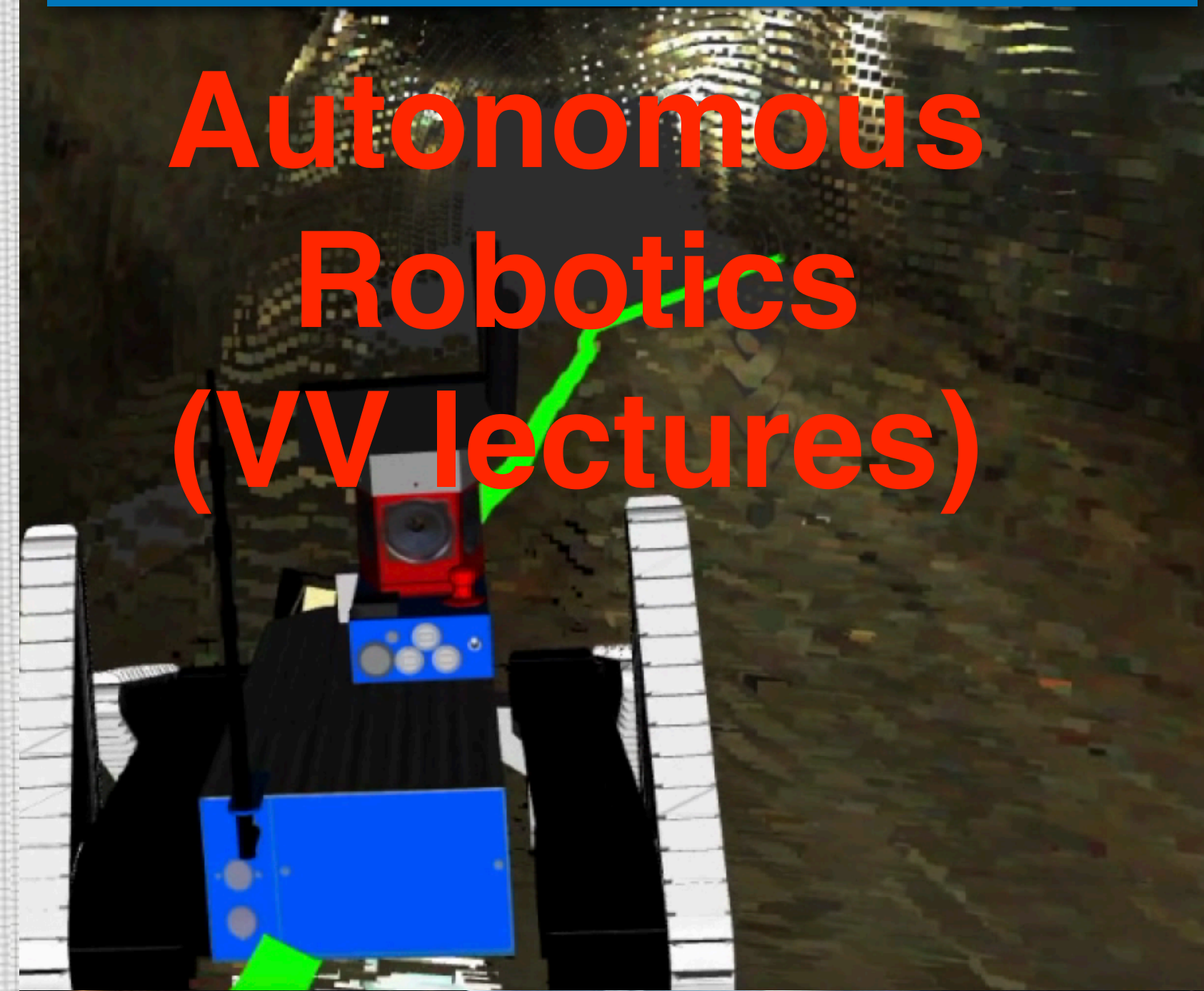
Mapping & localisation

Autonomous Robotics (KZ lectures)



Planning for exploration

Autonomous Robotics (VV lectures)



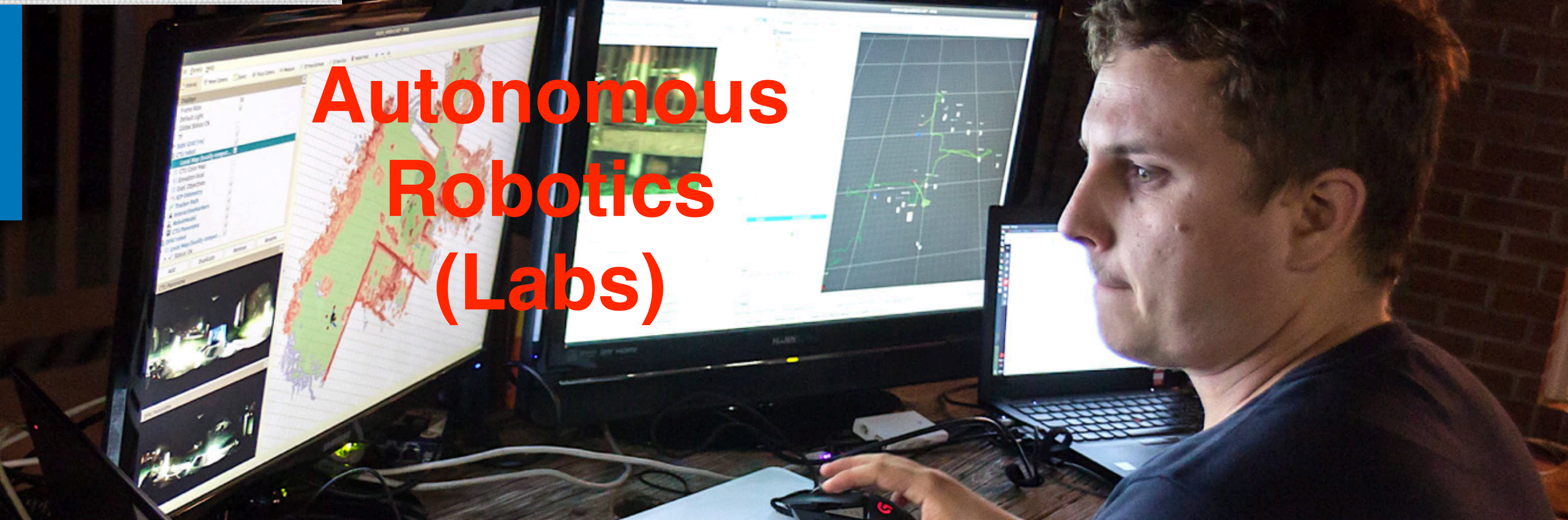
Object detection

Vision for Robotics



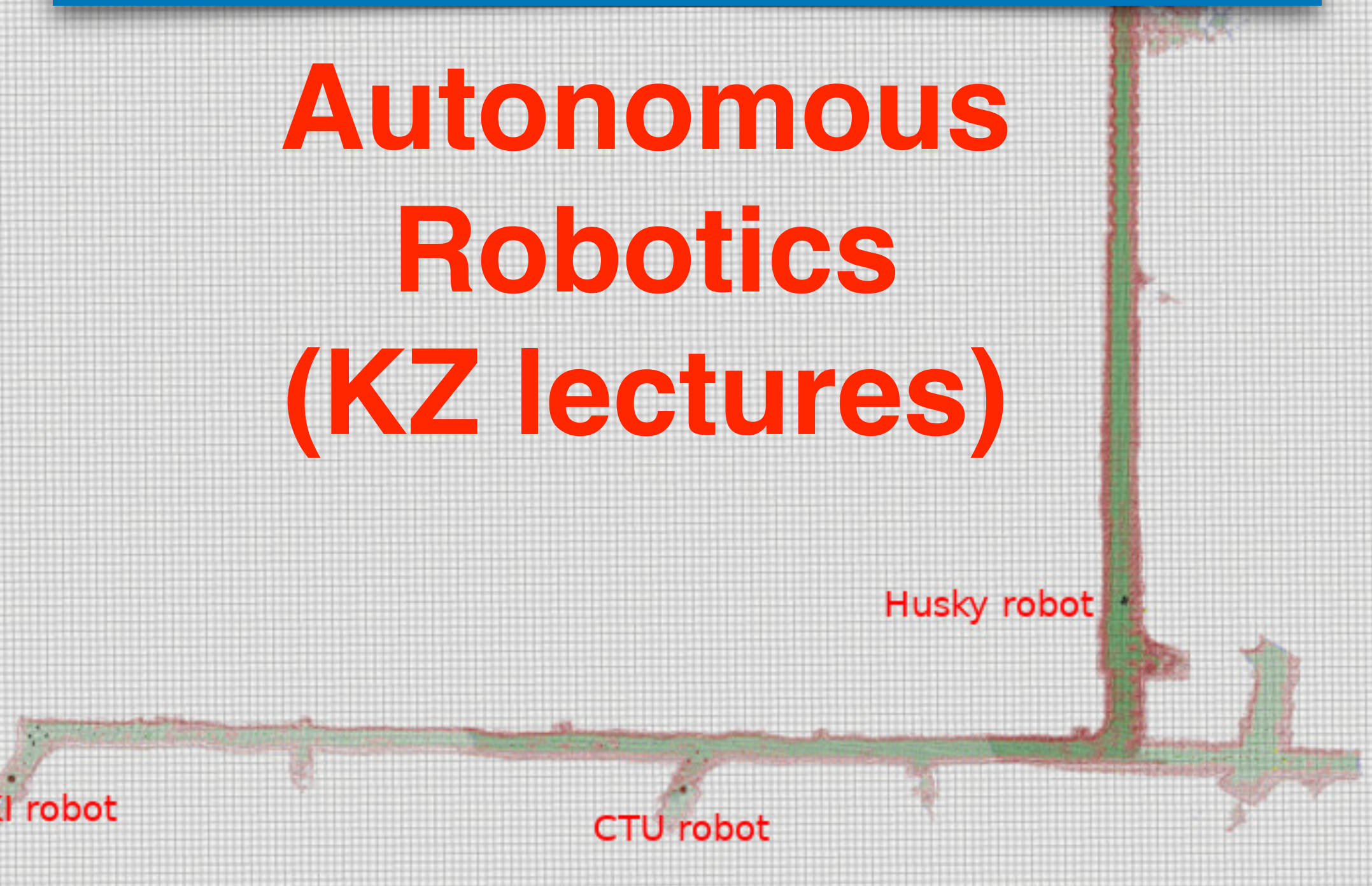
development,
visualization and
high-level control

Autonomous Robotics (Labs)



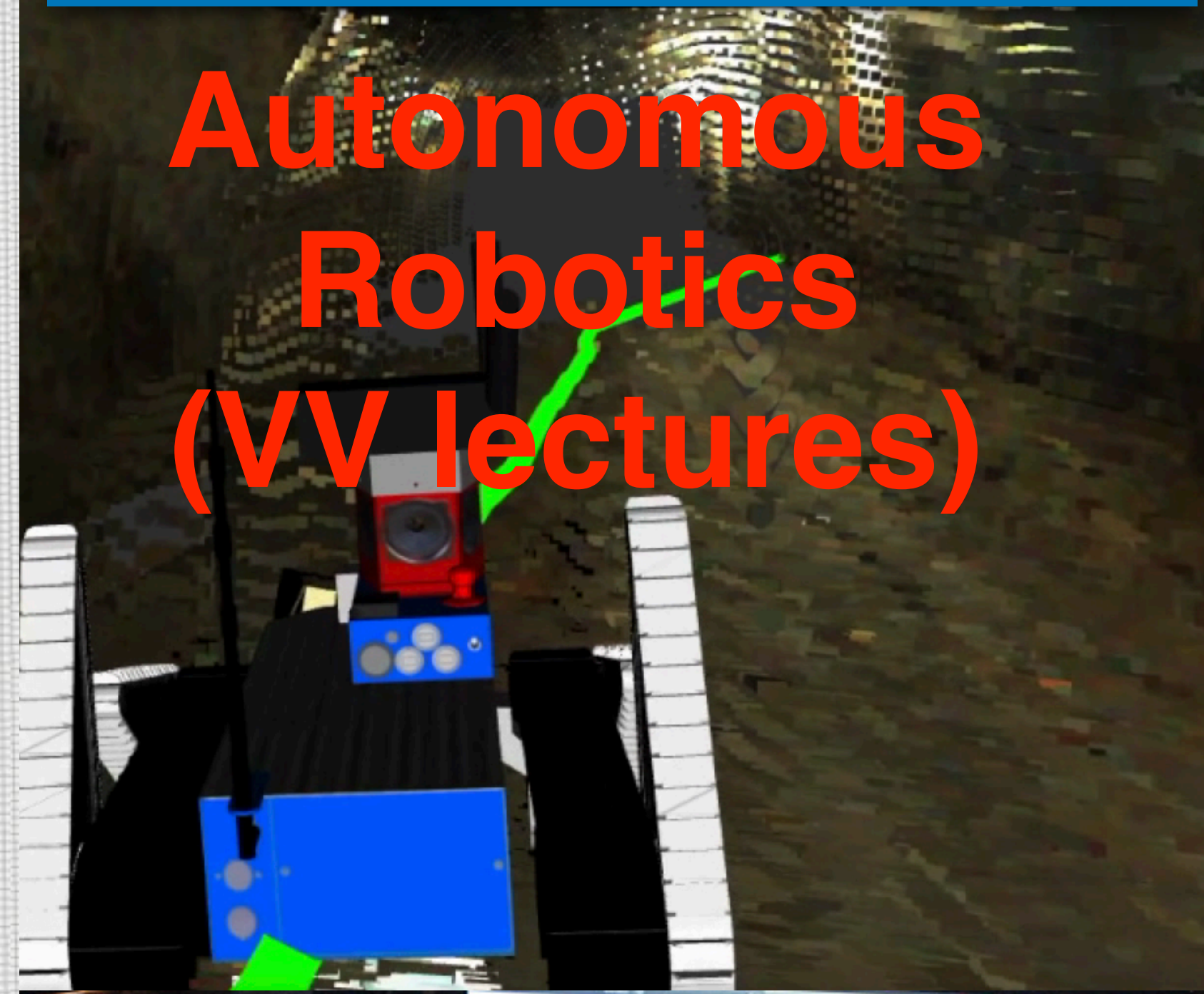
Mapping & localisation

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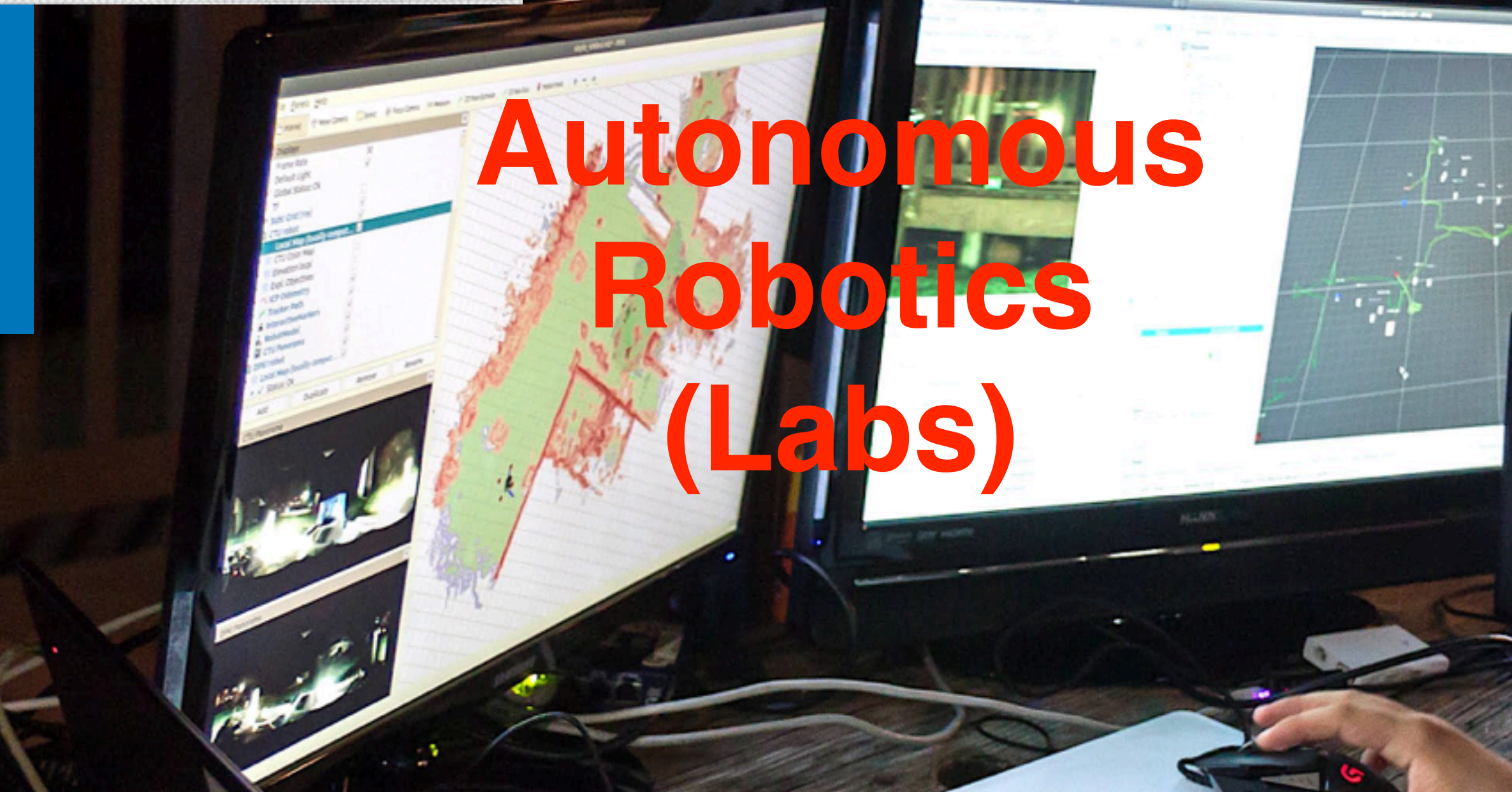
Object detection

Vision for Robotics



development,
visualization and
high-level control

Autonomous Robotics (Labs)



team

Key essence of the victory is relaxed team



Key essence of the victory is relaxed team

tunnel circuit

urban circuit

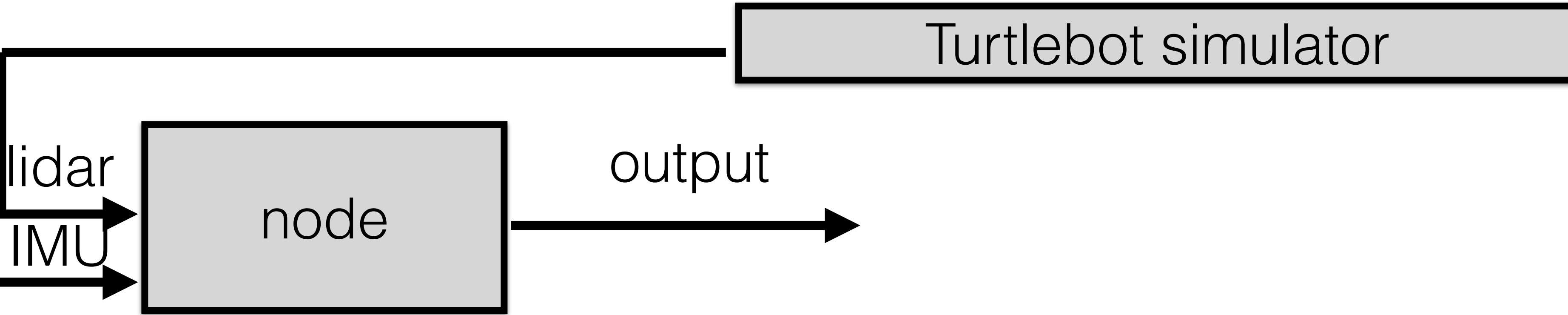
This component is not covered by the course, but you are encouraged to practise “being relaxed” on you own ;-)

- Autonomous robotics course = “How we do it”
- Semestral work=“Autonomous exploration of the unknown environment by Turtlebot”



Outline:

- Who are we and what are we doing?
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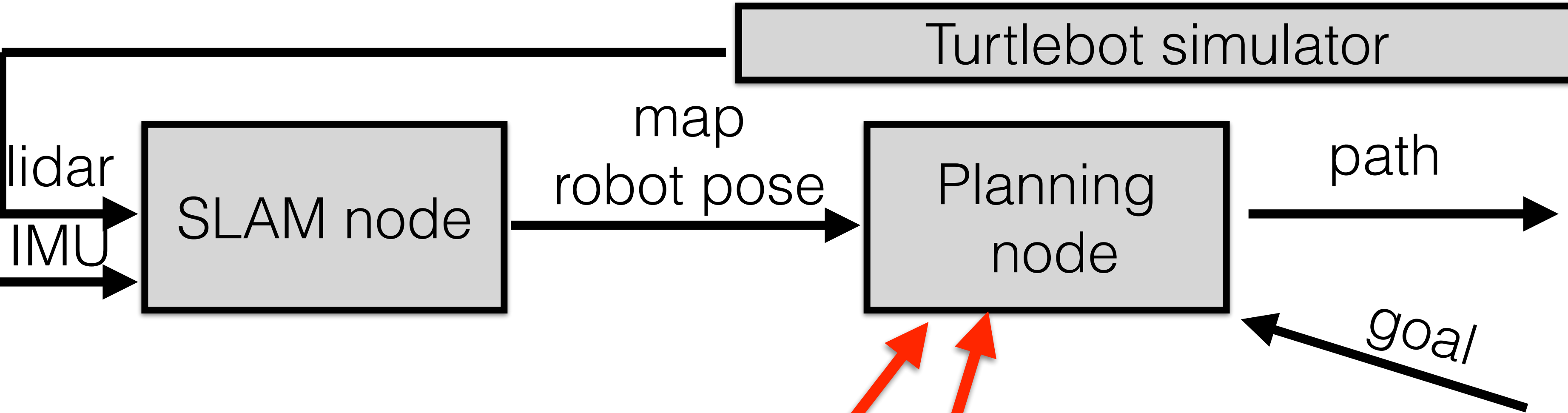


Lectures:

- Simultaneous localisation and mapping (KZ)
- Planning (VV)
- Remaining lectures (not necessary for solving the SW)

Labs:

- ROS
- SLAM from lidar + IMU + markers
- Motion control & Planning
- Semestral work (3 weeks)

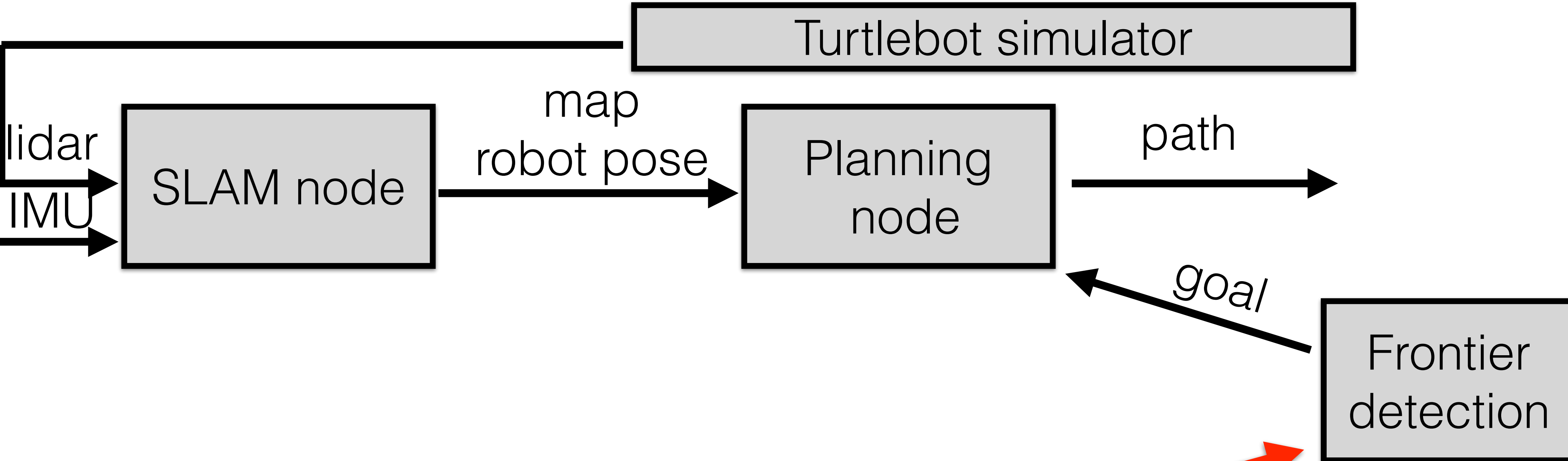


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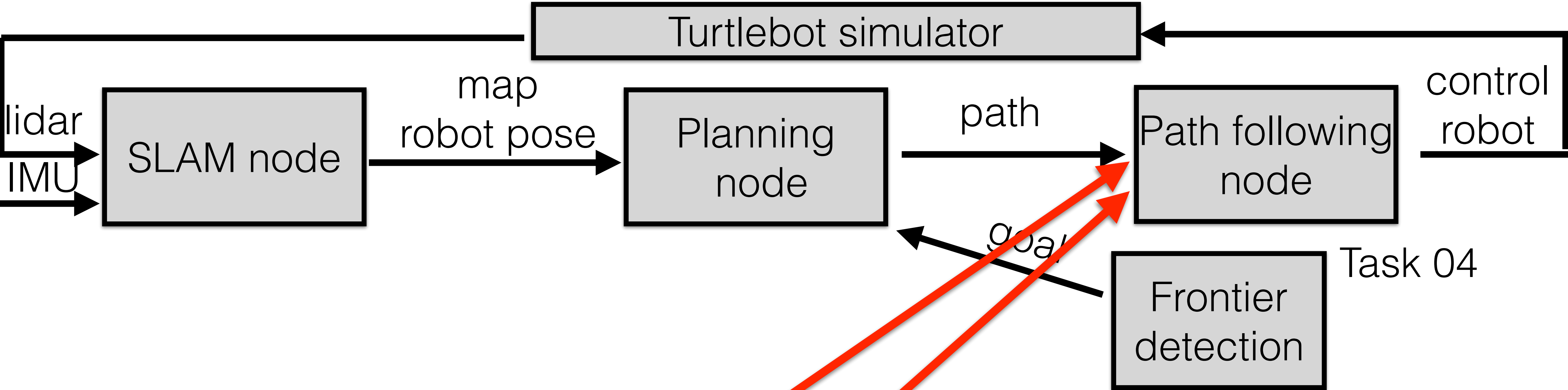


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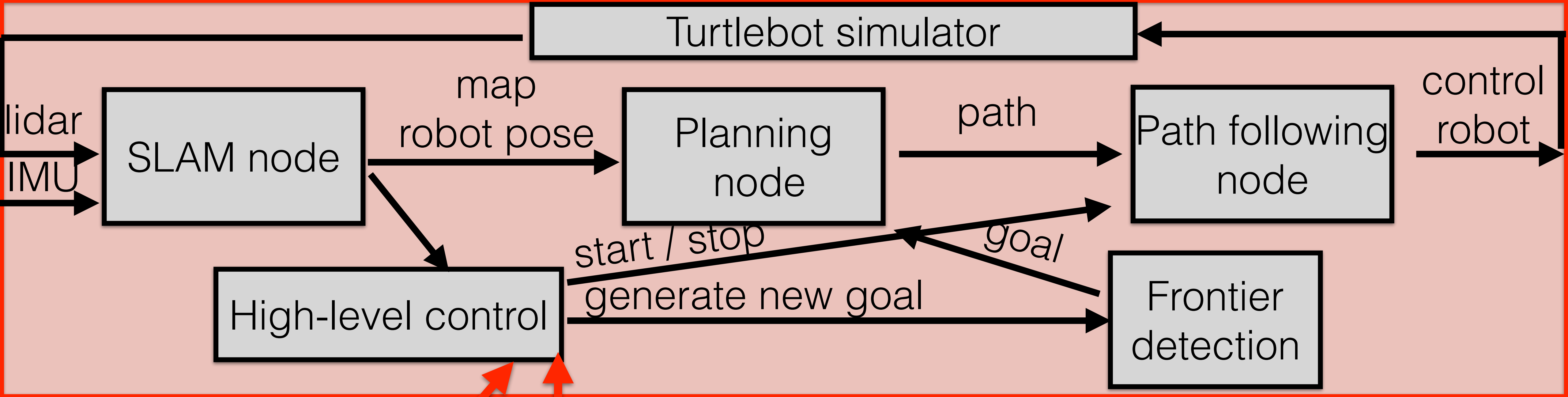


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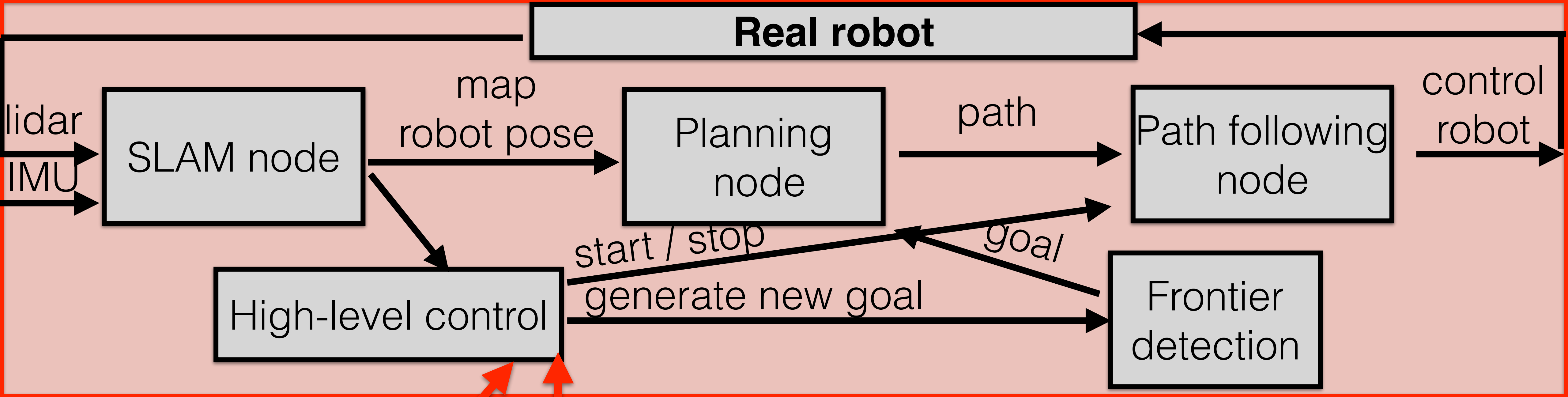


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- ROS
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- Motion control & Planning
- Semestral work (3 weeks)

Outline

Max 100 points

- 35p from homework $5 \times 5p + 1 \times 10p = 35$
- 20p from semestral work (10p simulation + 10p real robots)
- 45p points from exam test

Final grade determined by the number of achieved points:

No of points	Exam assessment
0-49	F
50- 59	E
60-69	D
70-79	C
80-89	B
90-100	A

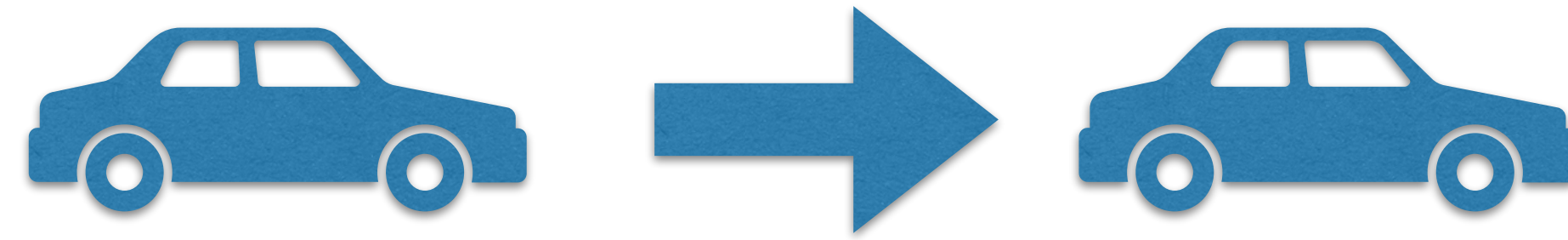
Minimum credit requirements:

- get at least 0 points all HWs + explore at least 50% of map in SW
- active participation in regular labs

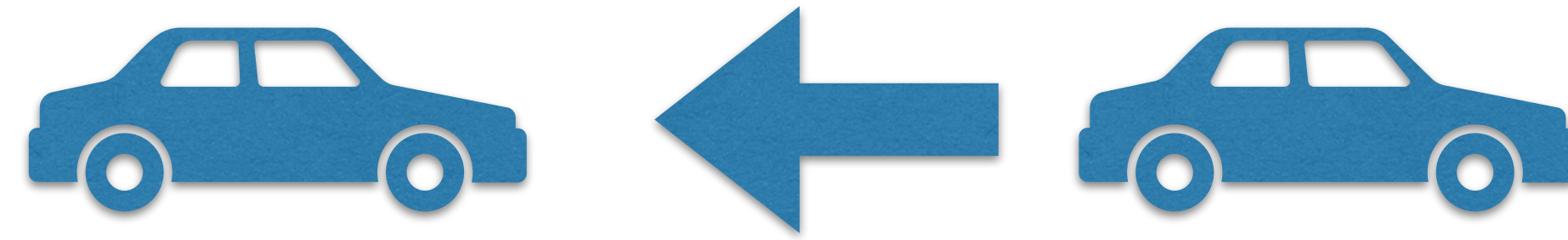
- Mutual (active) localization of several robots



- Mutual (active) localization of several robots



- Mutual (active) localization of several robots



Diploma thesis in our group

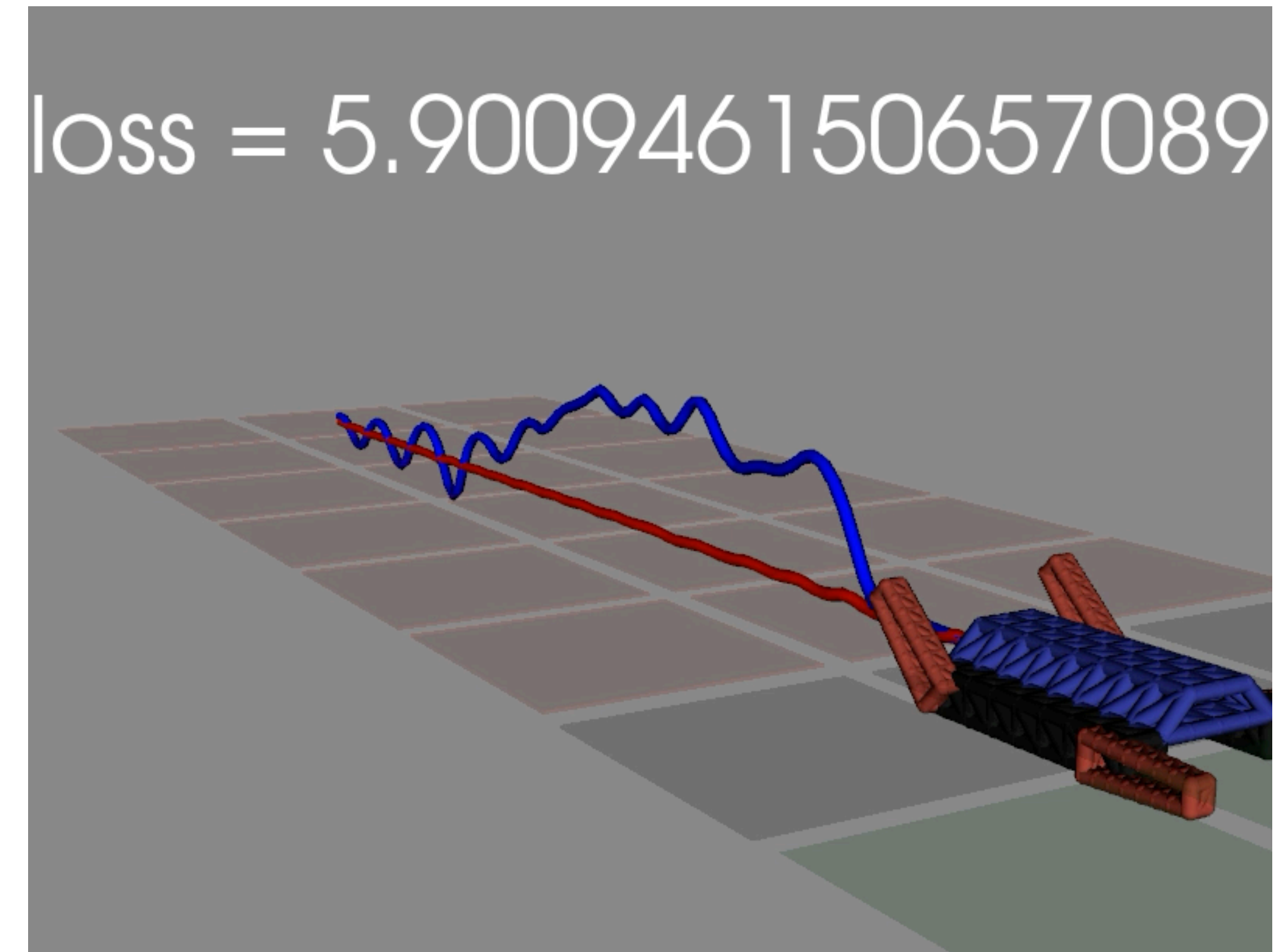
- Mutual (active) localization of several robots



- Mutual (active) localization of several robots



- Estimating terrain traversability



How to start?

Unofficial & preliminary assignment of the semestral work:

https://cw.fel.cvut.cz/b212/courses/aro/tutorials/semestral_work

Working on our servers:

https://cw.fel.cvut.cz/b212/courses/aro/tutorials/remote_access

Working on your computers:

<https://cw.fel.cvut.cz/b212/courses/aro/tutorials/ros>