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The University of Dublin

CONNECT
Networks of the Future

REV International Conference on Remote Engineering and Virtual Instrumentation

Remote Experimentation from Research to Education

A European Roadmap

Dr. Johann M. Marquez-Barja
Senior Research Fellow – Adjunct Lecturer
marquejm@tcd.ie / www.marquez-barja.com

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Jeff Sheldon

Acknowledgements

FED4FIRE

FORGE
Forging Online Education through FIRE

FIRE

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Trinity College Dublin
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The University of Dublin

Sue Huan

Prof. Luiz DaSilva
dasilval@tcd.ie
Dr. Nicholas Kaminski
kaminskn@tcd.ie
Mr. Francisco Paisana
paisanaf@tcd.ie
Mr. Joao F. Santos
facocalj@tcd.ie

REV International Conference on Remote Engineering and Virtual Instrumentation

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Trinity College Dublin

Ollscoil Átha Cliath | The University of Dublin

- The University of Dublin, Trinity College was founded in 1592
- 2015QS ranking:
  - 1st in Ireland
  - 77st worldwide
  - Top 1% School of Engineering worldwide
- Only Irish university to rank in the top 100 world universities and amongst the top 50 European universities by the Times Higher Education Supplement
- Approximately 16,000 students
- Approximately €154m in research income per year

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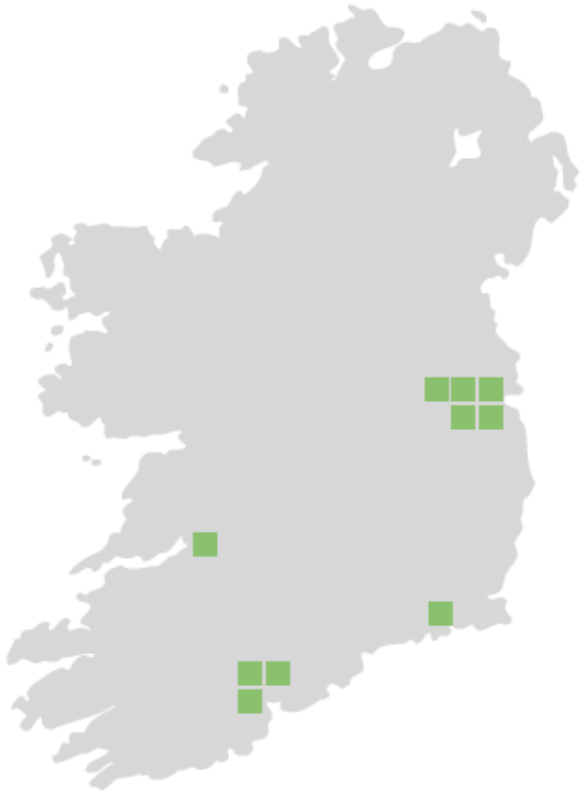


10 ACADEMIC INSTITUTIONS

10 PRINCIPAL INVESTIGATORS

35 FUNDED INVESTIGATORS

77 PATENTS

7099 PUBLICATIONS

39 SPIN OUT COMPANIES

81 LICENSES

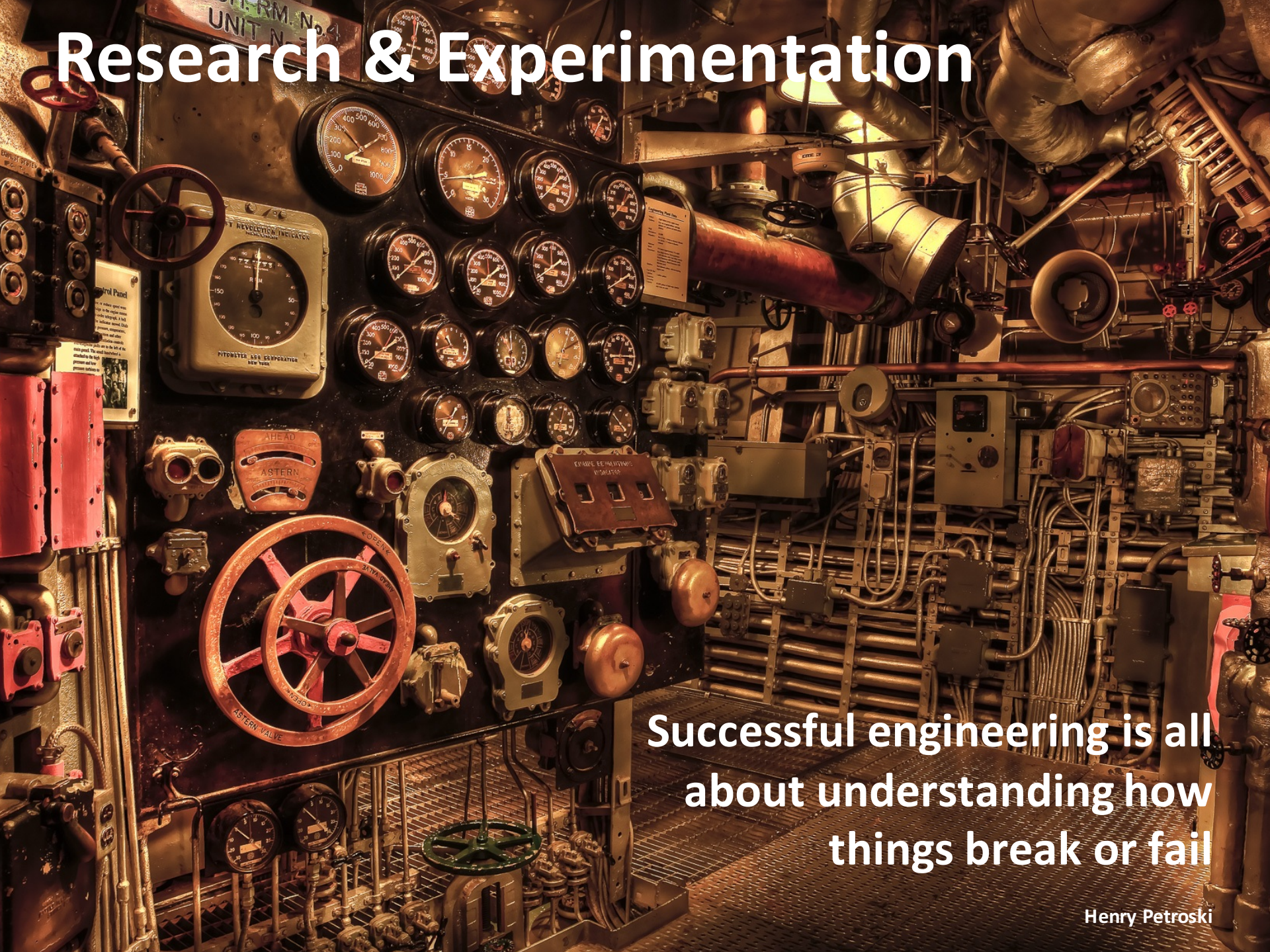
4 IEEE FELLOWS

970 GRADUATES

40 INTERNATIONAL JOURNAL EDITORIAL BOARDS

TCD WIRELESS / OPTICAL NETWORKING / COGNITIVE AND SOFTWARE RADIO / THERMAL FOR RF **DIT** ANTENNAS **DCU** OPTICAL SYSTEMS **NUIM** RF DESIGN / NETWORKING / PRIVACY **UCD** RF DESIGN / NETWORKING PRIVACY **UCC** MOBILE COMMUNICATIONS / SENSOR NETWORKS / NETWORK SECURITY / NETWORK OPTIMISATION **TYNDALL** MICROELECTRONICS / SMART SENSORS / COMMUNICATIONS **CIT** IOT SERVICES / SENSOR NETWORKS / TELECOMMUNICATIONS **UL** THERMAL MANAGEMENT FOR WIRELESS & OPTICAL MICROELECTRICALS **WIT TSSG** NETWORK MANAGEMENT / CLOUD COMPUTING

Research & Experimentation



Successful engineering is all about understanding how things break or fail

Henry Petroski

Engineering and experimentation

Reinforcement and demonstration through experimentation are extremely important for understanding physics and engineering phenomena, especially wireless communications and its physical properties.

The most effective way to demonstrate such physical properties and the impairments of wireless signals is through radio experimentation on top of well equipped radio testbeds

"Virtualizing testbed resources to enable remote experimentation in online telecommunications education", Johann M. Marquez-Barja, Nicholas Kaminski, Francisco Paisana, Christos Tranoris, Luiz A. DaSilva. IEEE Global Engineering Education Conference (EDUCON15). pp 822-829. March, 2015. Tallinn, Estonia . ISBN 978-1-4799-1907-9/15/.

EU Research and Innovation

Research Infrastructures (RI)

EU support for RIs in the context of its Framework Programmes (FPs)

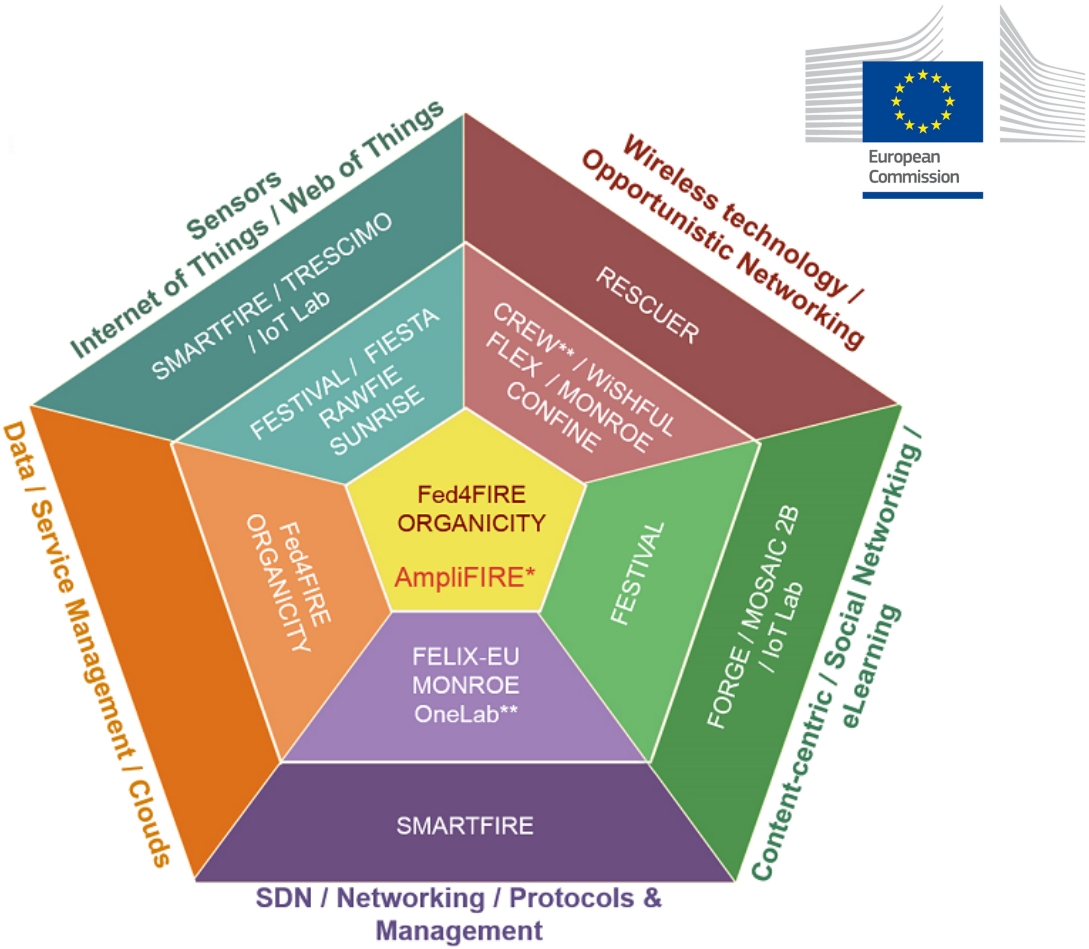
- FP2 (1987-1991) €30 million
- FP7 (2007-2013) €1.85 billion
- Horizon 2020 (2014-2020) €2.5 billion
  - New world-class research infrastructures
  - Optimizing the use of the national facilities
  - ICT based **e-infrastructures** which are essential to enable **access to distant resources**, **remote collaboration**, and **massive data processing** in all scientific fields

https://ec.europa.eu/programmes/horizon2020/en/area/research-infrastructures

Future Internet Research Experimentation FIRE

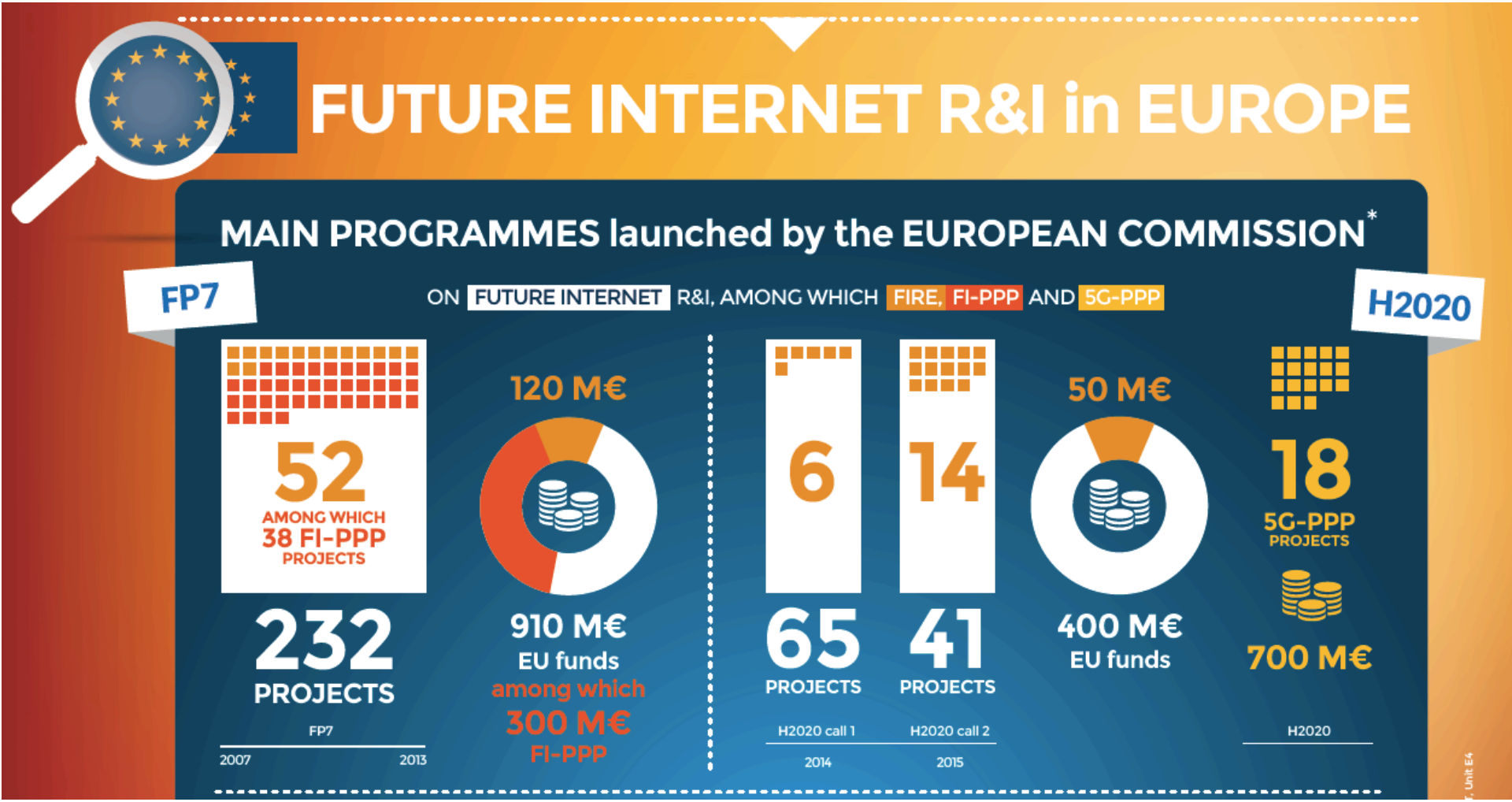
European Commission initiative

- FIRE initiative is a European endeavour that promotes the creation of wide-scale federations of high-performance testbed and experimentation facilities for internet and network-related research.



LARGE-SCALE EXPERIMENTAL TESTBEDS

EC budget



SmartFIRE project, ICT 2015 Conference

Experimentation-based Research

FIRE Projects

Smart Reconfigurable Radio Testbed

Trinity College Dublin
The University of Dublin

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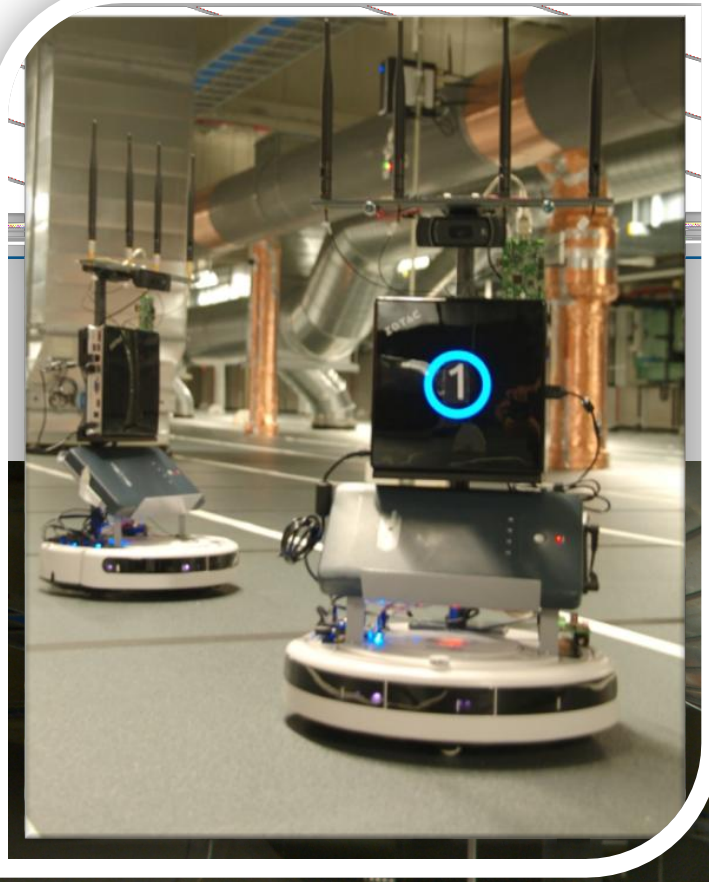
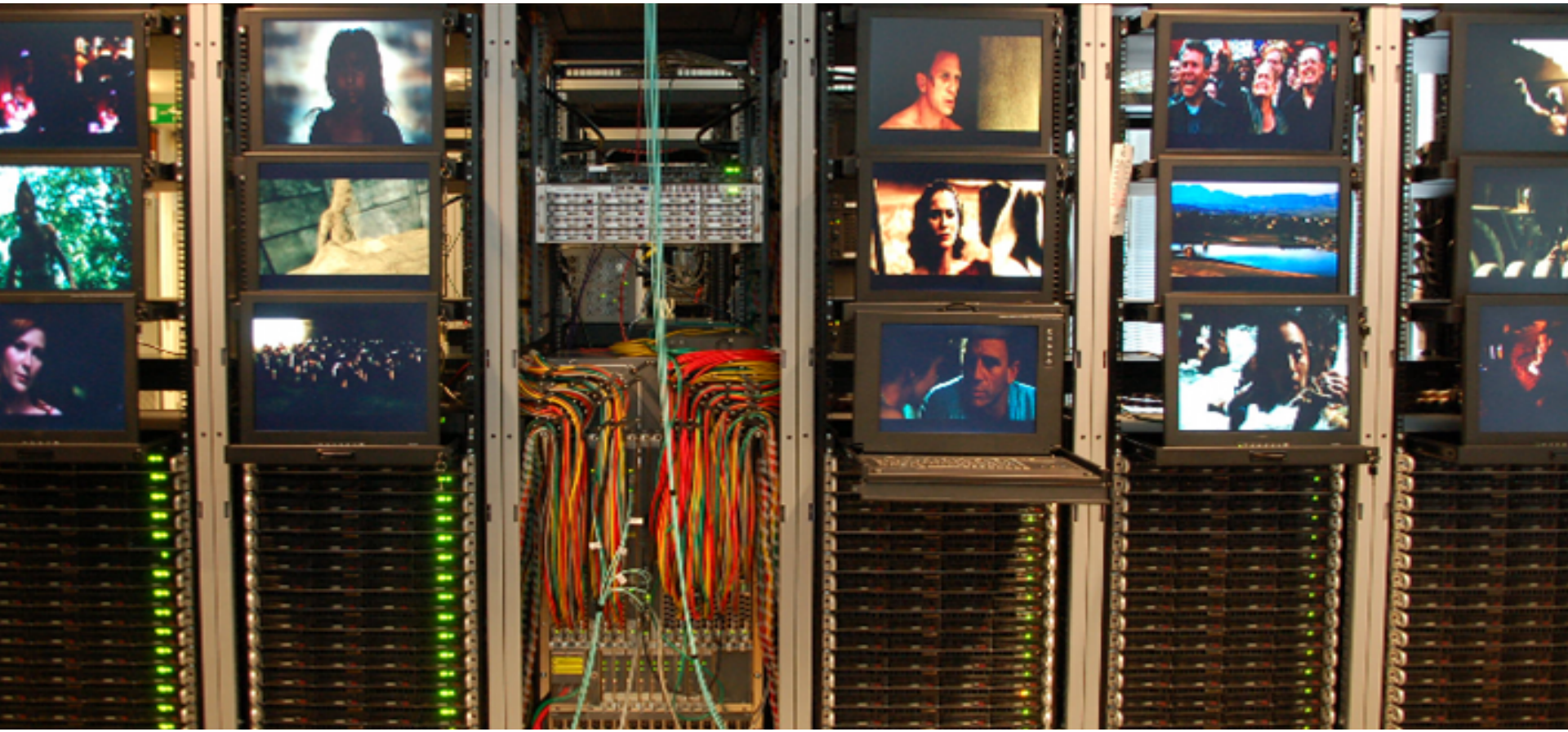
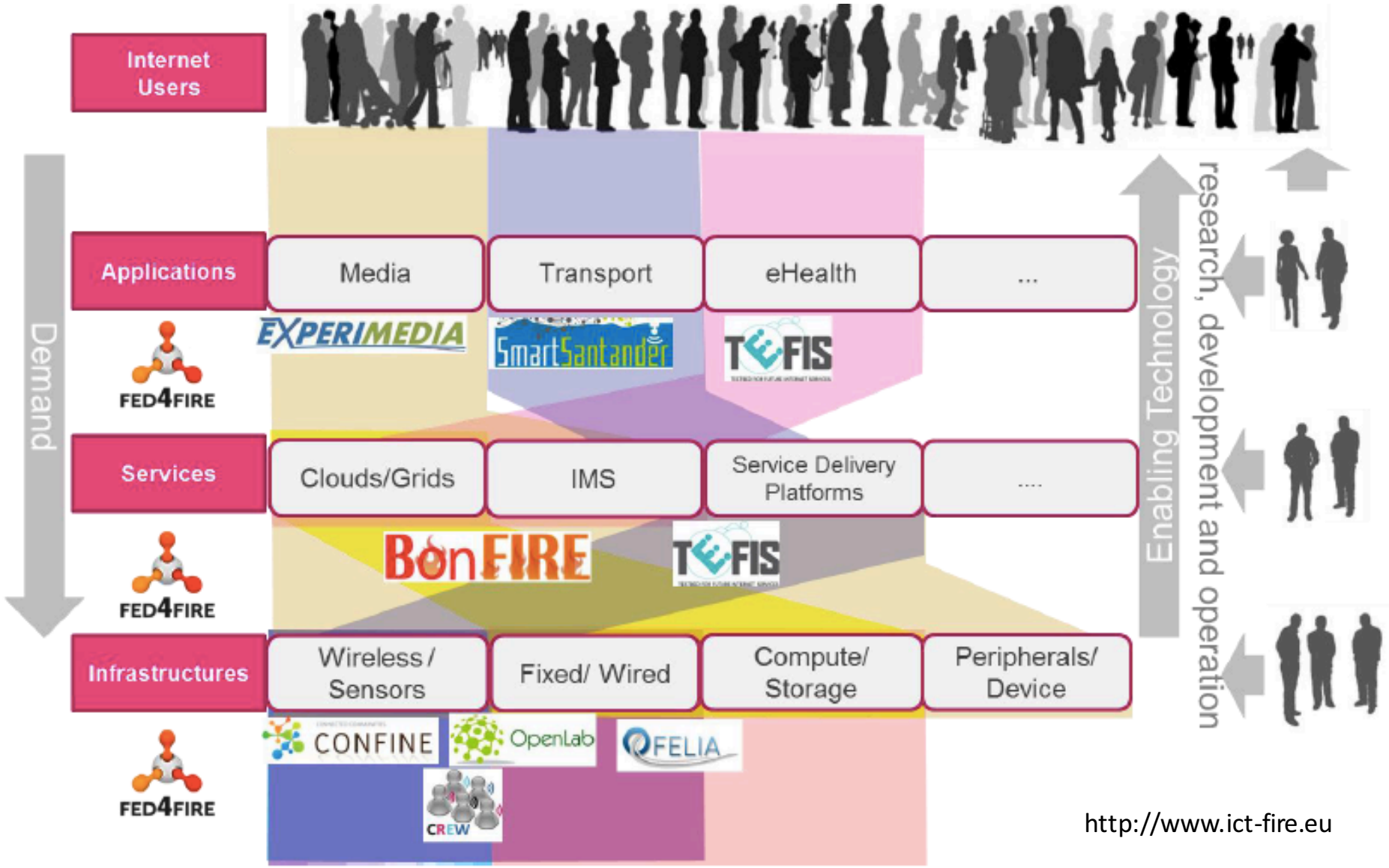


ilab.t
technology centre
http://ilabt.iminds.be

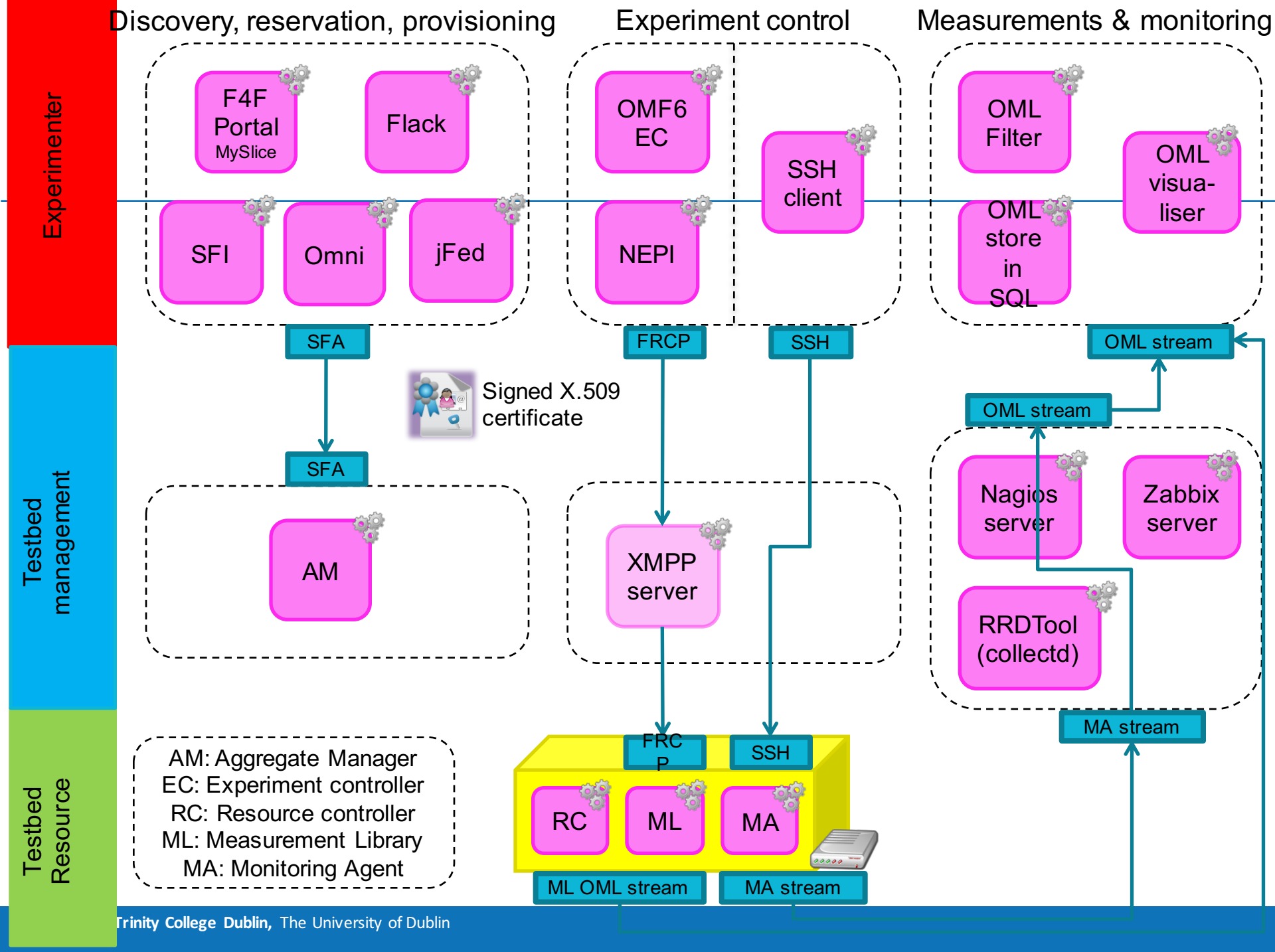


Some FIRE facilities

The focus of the FIRE Facilities



http://www.ict-fire.eu


Discovery, reservation, provisioning
Experiment control
Measurements & monitoring
Experimenter
Testbed management
Testbed Resource
F4F Portal
MySlice
Flack
SFI
Omni
jFed
OMF6 EC
NEPI
SSH client
OML Filter
OML store in SQL
OML visua-liser
SFA
FRCP
SSH
OML stream
Signed X.509 certificate
SFA
OML stream
AM
XMPP server
Nagios server
Zabbix server
RRDTool (collectd)
MA stream
AM: Aggregate Manager
EC: Experiment controller
RC: Resource controller
ML: Measurement Library
MA: Monitoring Agent
FRC P
SSH
RC
ML
MA
ML OML stream
MA stream

Education & Experimentation

Learning and education

Learning underpins human society as an essential activity for societal advancement as well as personal well-being

In 2009 the European Union budget on education was 6.2% of the European Gross Domestic Product

The recent economy crash has forced a reduction in educational in several countries

Innovative solutions to provision cost-effective high quality learning are needed

"FORGE: Enhancing elearning and research in ICT through remote experimentation", Johann M. Marquez-Barja, Guillaume Jourjon, Mikroyannidis Alexander, Christos Tranoris, John Domingue, Luiz A. DaSilva. IEEE Global Engineering Education Conference (EDUCON14). pp 1157-1163. April, 2014. Istambul, Turkey . ISBN 978-1-4799-3191-0.

Experimentation is a key component of engineering education

- **Physical experimentation**
  - Expensive, in particular for low-budget institutions
  - Deploying and maintaining experimental facilities is costly
  - Developing cutting edge telecommunications technologies requires massive effort and budget
  - Learners constrained by location and lab opening hours
- **Online laboratories**
  - Online laboratories provide remote access to experiments allowing students to access experiments without time and location restrictions
  - FORGE project's initiative towards empowering education by enabling hands-on remote experimentation
  - Trinity College Dublin is focused on enhancing online telecommunications engineering education by enabling hands-on remote experimentation over its Smart Reconfigurable Radio Testbed

"Assessing the impact of remote hands-on experimentation on engineering students", Johann M. Marquez-Barja, Nicholas Kaminski, Guillaume Jourjon, Jono Vanhie-Van Gerwen, Daan Pareit, Luiz A. DaSilva. IEEE Transactions on Education. [In preparation], 2015.

Online laboratories

Summarized taxonomy

- **Virtual labs**
  - software-based laboratories
  - simulation tools
- **Remote labs**
  - Experimentation on real lab equipment
- **Hybrid labs**
  - Output data from real measurements/equipment
  - Processed by simulation tools

"Virtual Labs Project: A Paradigm Shift in Internet-Based Remote Experimentation," R. Bose, IEEE Access, vol. 1, pp. 718–725, 2013. Available: http://dx.doi.org/10.1109/access 2013.2286202

Education and experimentation

Experimentation-based projects

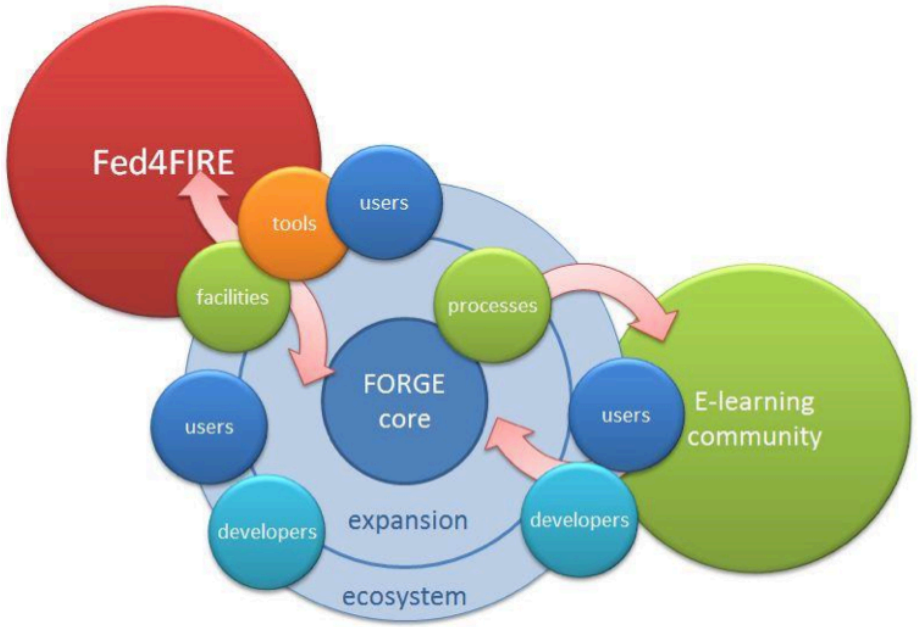

FORGE
Forging Online Education through FIRE
Forging Online Education through FIRE
The FORGE Project Consortium
ERGOTRON

Forging Online Education through FIRE (FORGE)

FORGE is a project bringing the FIRE and eLearning worlds together. In particular, FORGE aligns FIRE (Future Internet Research and Experimentation) with the ongoing education revolution.

FORGE specifies development methodologies and best practices for offering FIRE experimentation facilities to learners and to the learning community in general

The project leads to a strong connection between the learning community and existing FIRE platforms and supporting tools



"FORGE Toolkit: Leveraging Distributed Systems in eLearning Platforms", Guillaume Jourjon, Johann M. Marquez-Barja, Thierry Rakotoarivelo, Alexander Mikroyannidis, Kostas Lampropoulos, Spyros Denazis, Christos Tranoris, Daan Pareit, John Domingue, Luiz A. DaSilva, Max Ott. IEEE Transactions on Emerging Topics in Computing, 2015.

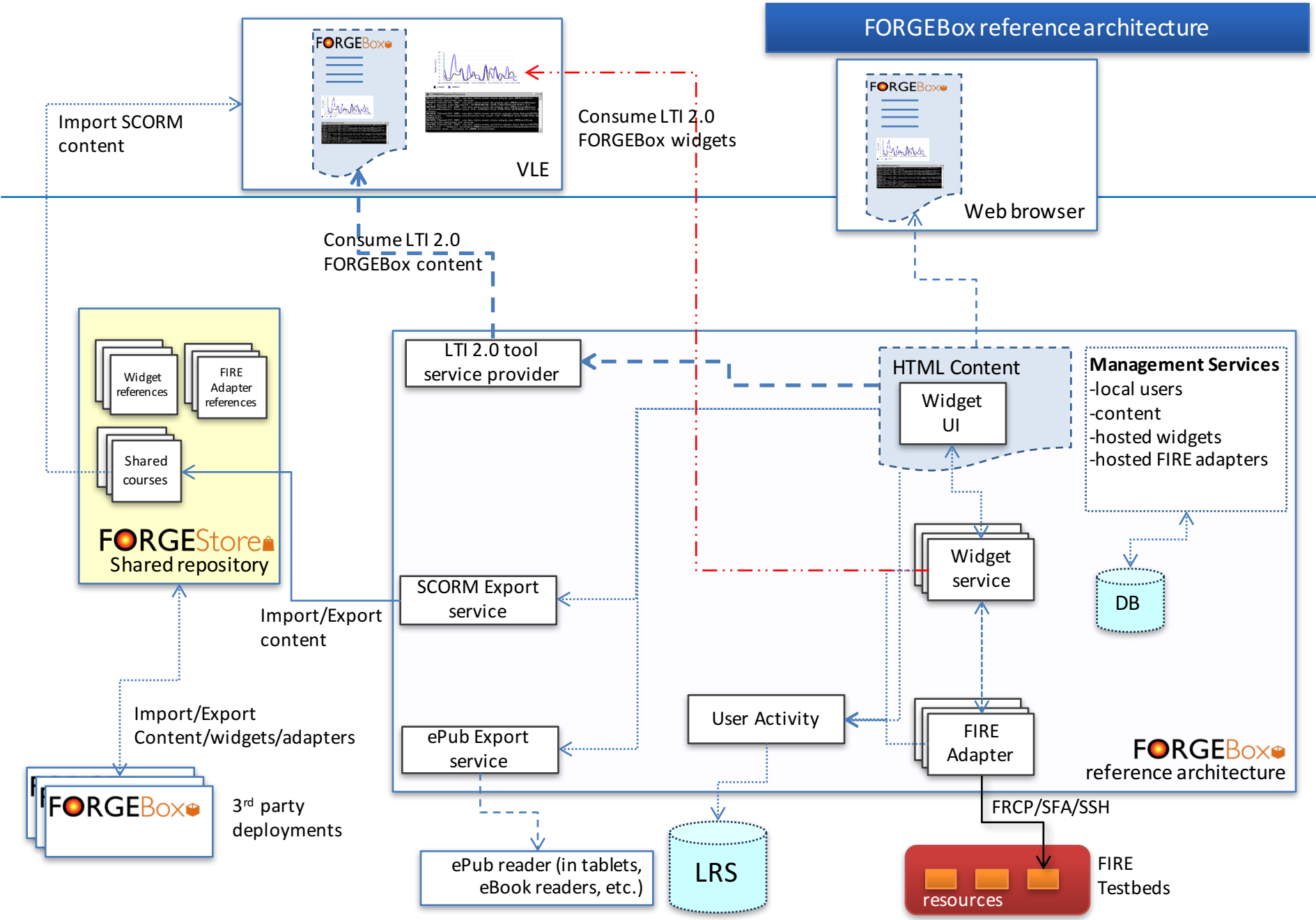
FORGE objectives

FORGE
Forging Online Education through FIRE

FORGE is transforming the FIRE facilities, already vital for European research, into a learning resource for higher education, enabling educators to easily create experiment-based learning resources

FORGE allows educators to create, use and re-use FIRE-based learning experiences through our tools and techniques

FORGE enables equity of access to the latest ICT systems and tools independent of location and at low cost. Experimental facilities are expensive!!!

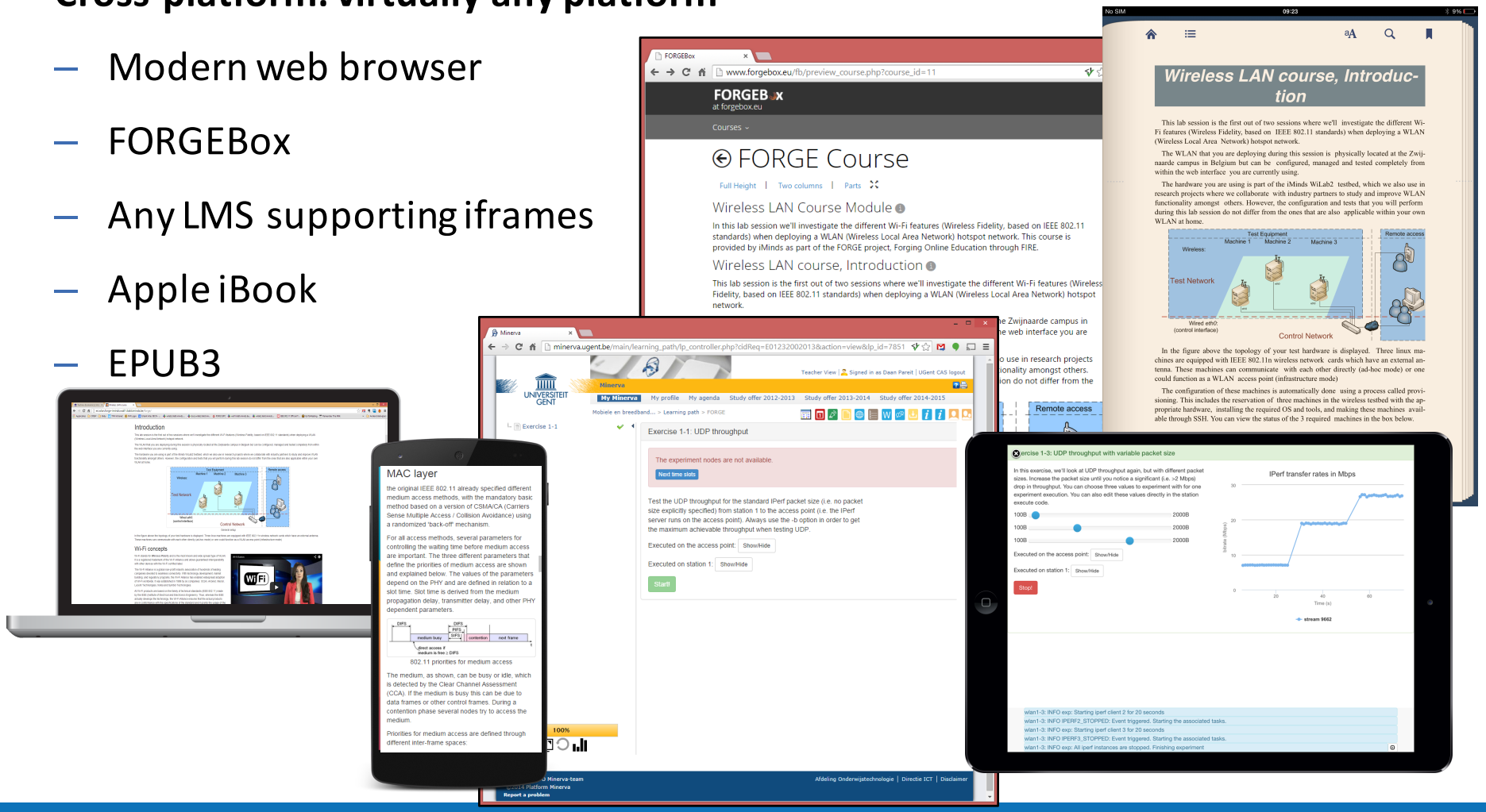

FORGEBox reference architecture
Import SCORM content
VLE
Consume LTI 2.0 FORGEBox widgets
Web browser
Consume LTI 2.0 FORGEBox content
Widget references
FIRE Adapter references
Shared courses
FORGEStore
Shared repository
LTI 2.0 tool service provider
HTML Content
Widget UI
Management Services
-local users
-content
-hosted widgets
-hosted FIRE adapters
Widget service
DB
SCORM Export service
Import/Export content
Import/Export Content/widgets/adapters
User Activity
FIRE Adapter
ePub Export service
FORGEBox reference architecture
FORGEBox
3rd party deployments
FRCP/SFA/SSH
ePub reader (in tablets, eBook readers, etc.)
LRS
resources
FIRE Testbeds

Resulting web widgets + iBook

FORGE
Forging Online Education through FIRE

Cross-platform: virtually any platform

- Modern web browser
- FORGEBox
- Any LMS supporting iframes
- Apple iBook
- EPUB3




FORGE Methodology

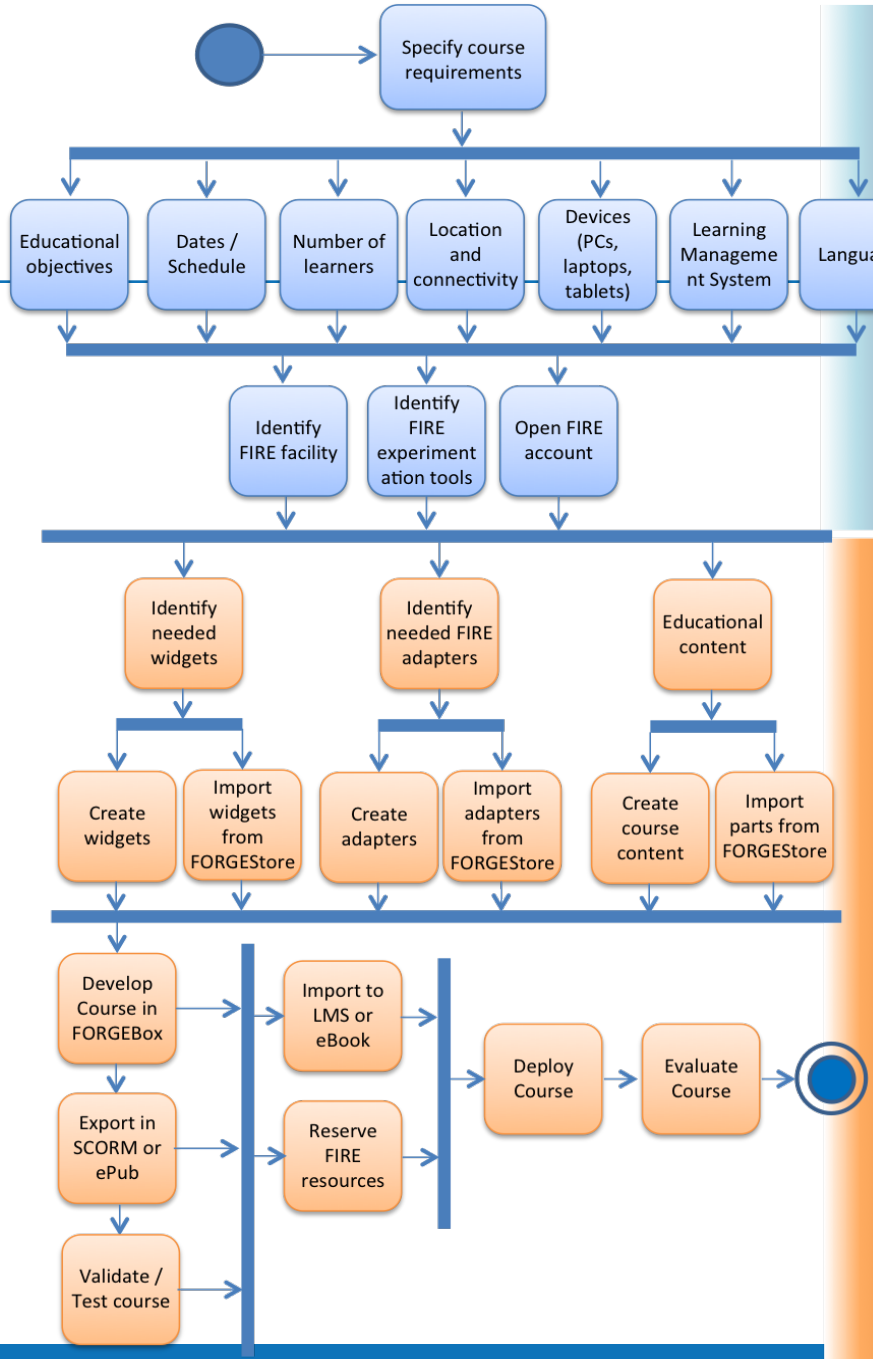
FORGE Methodology

Creating FIRE courseware

Two main stages

- Course preparation
- FORGE supported activities

(http://www.forgebox.eu/fb/preview_course.php?course_id=78)



"A methodology for the design, delivery and evaluation of learning resources for remote experimentation", Alexander Mikroyannidis, Aitor Gomez-Goiri, John Domingue, Christos Tranoris, and Johann M. Marquez-Barja. IEEE Global Engineering Education Conference (EDUCON16). [to appear], 2016. Abu Dhabi, United Arab Emirates

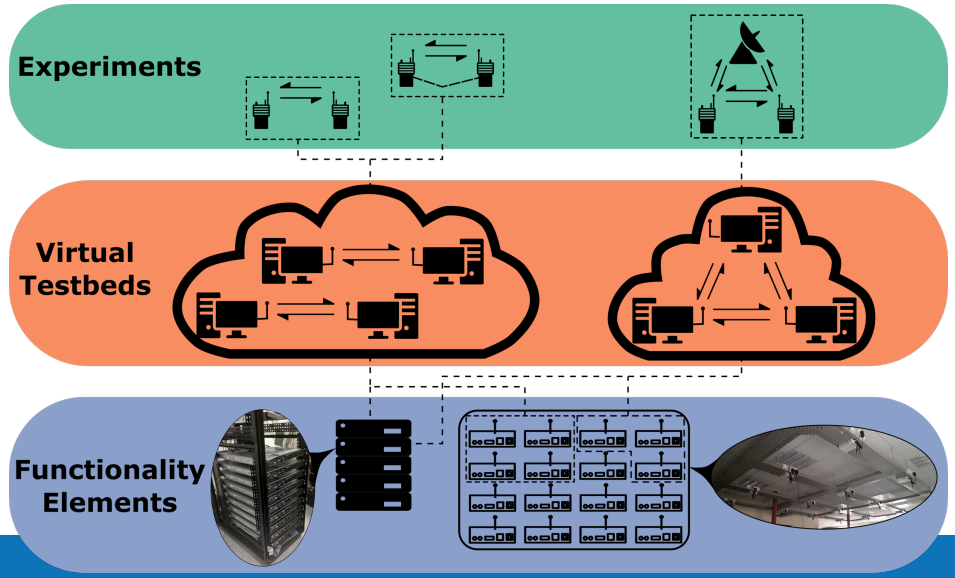
Specifying course requirements

Dynamic spectrum access & wireless signalling – Use case

- Lab sessions within a master course on wireless networks and communications systems
- Basic knowledge of wireless comms systems is a pre-requisite for this lab
- Learning outcomes:
  - Understanding of the impairments to wireless comms
  - Gaining tangible experience with interference and interference-avoidance techniques
  - Understanding OFDM modulation
  - Understanding of Dynamic Spectrum Access techniques
  - Appreciation of realistic wireless applications

Identifying FIRE facilities

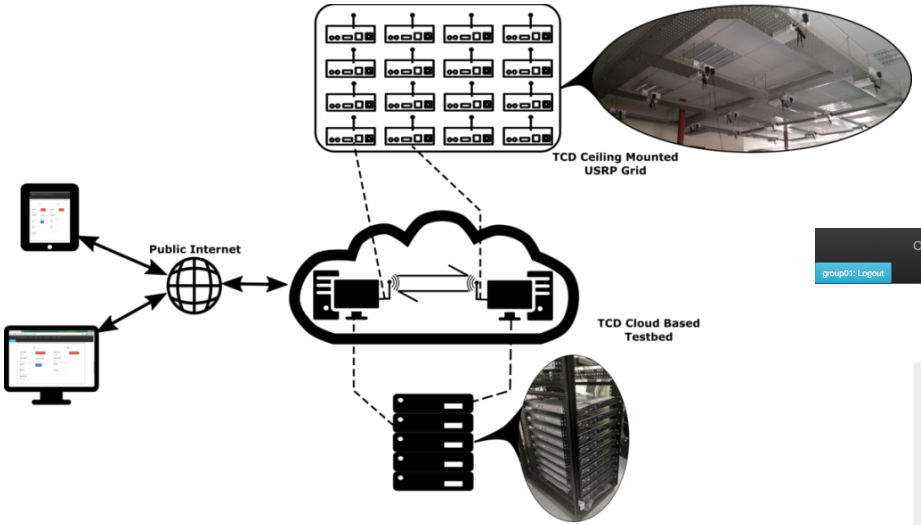
Dynamic spectrum access & wireless signalling – Use case



- Smart Reconfigurable Radio Testbed @ CONNECT, Trinity College Dublin, Ireland
  - USRPs in a grid configuration
  - Cloud-based computing VMs
  - Dedicated indoor testing environment

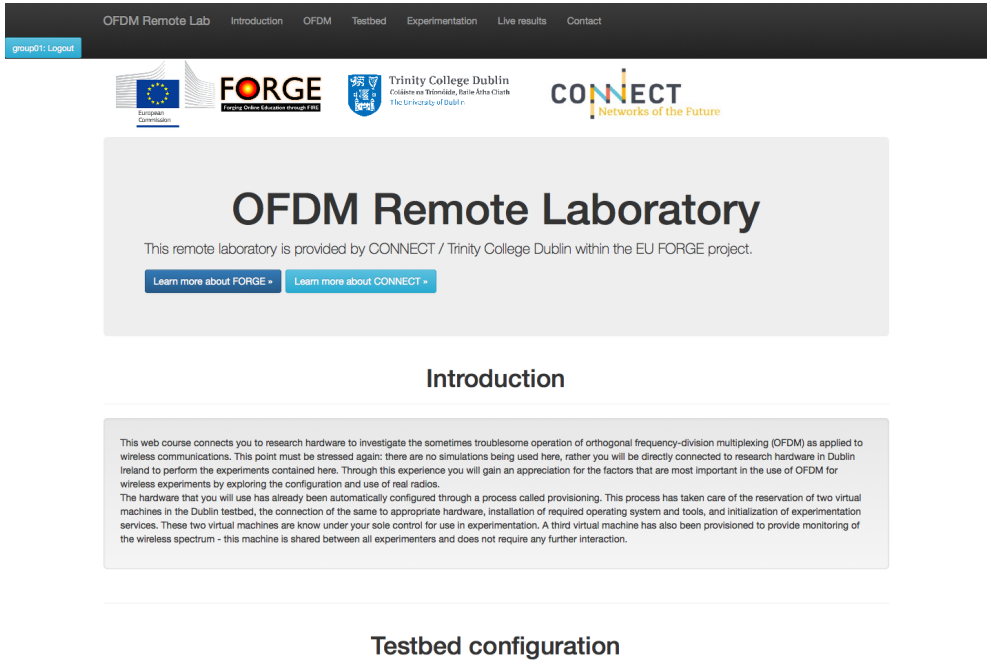
Authoring educational content

Dynamic spectrum access & wireless signalling – Use case



Reuse content of lecture slides

Multimedia material



Integration of FIRE facilities and content

Dynamic spectrum access & wireless signalling – Use case

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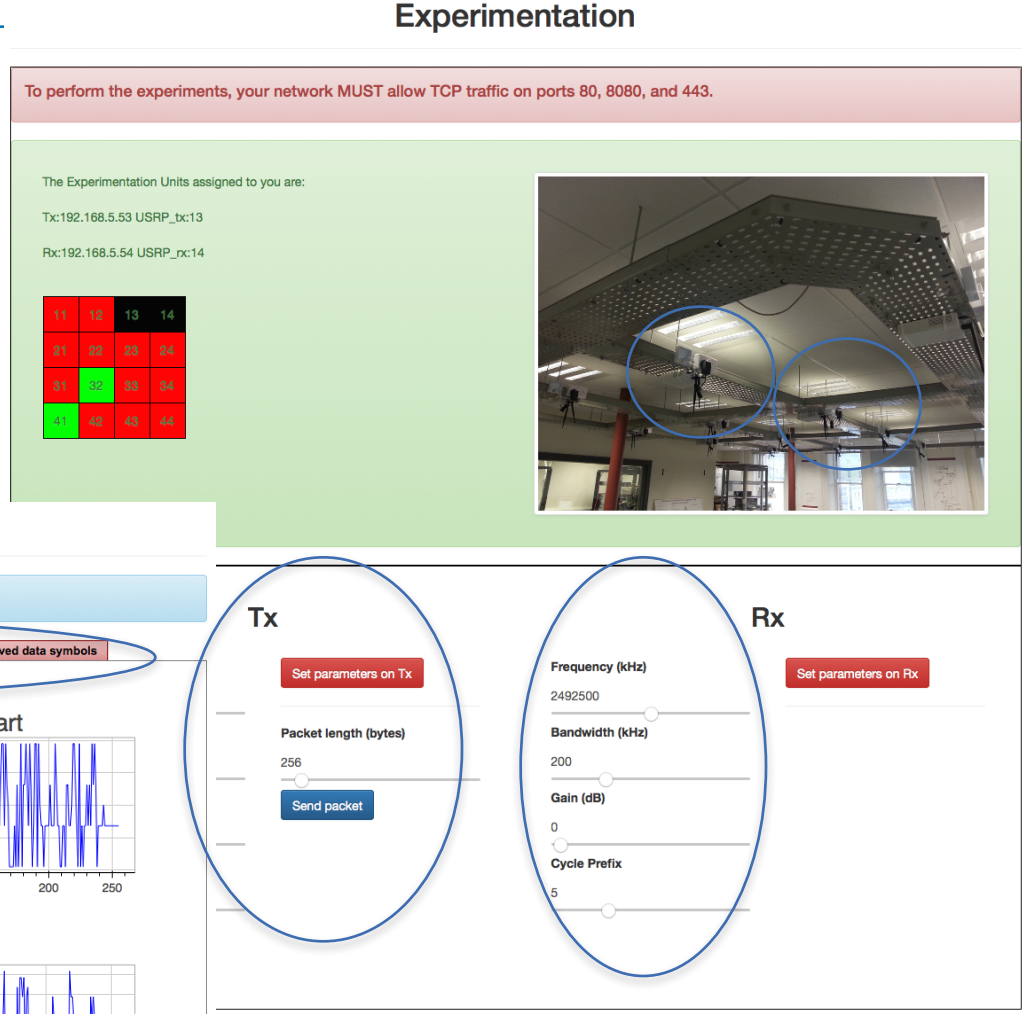
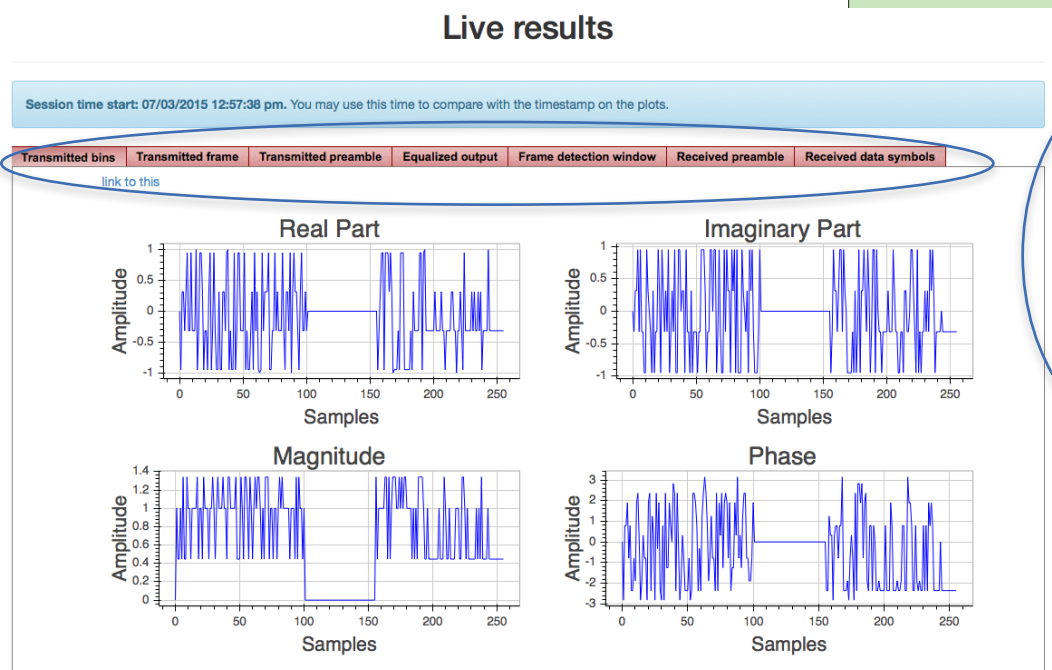
Interaction via widgets and FIRE adapters

- Control widgets
- Visualization widgets
- Adaptions for the specific testbed management system





Integration of FIRE facilities and content

Dynamic spectrum access & wireless signalling – Use case

FORGE
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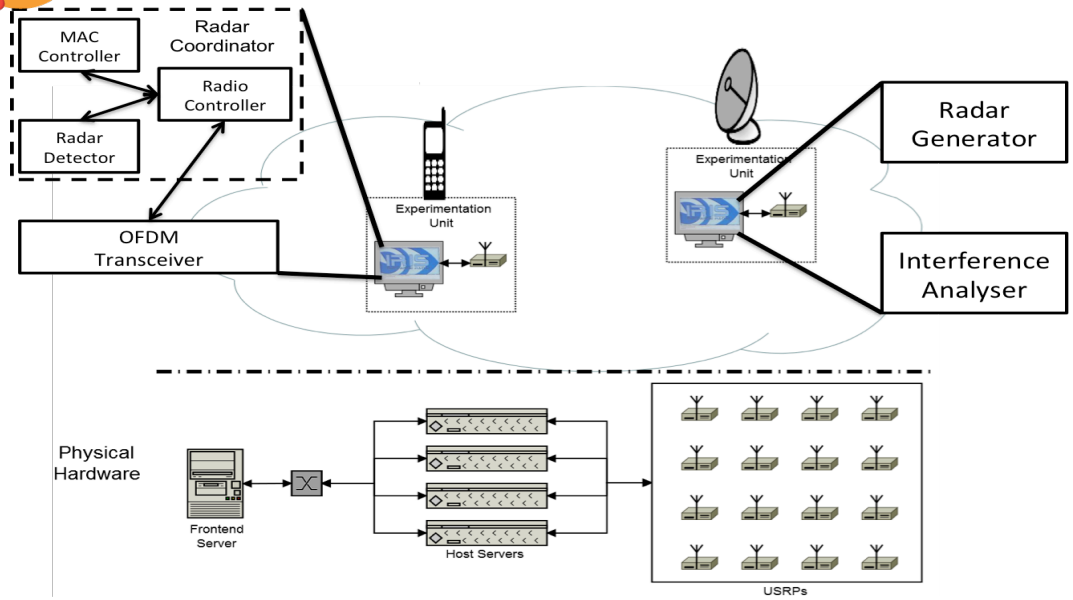
FED4FIRE

FIRE

CREW

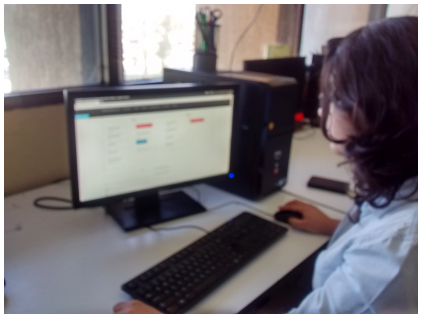


www.ict-forge.eu
www.fed4fire.eu
www.ict-fire.eu
www.crew-project.eu

Deployment and impact

Dynamic spectrum access & wireless signalling – Use case

- Trinity College Dublin, Ireland (March 2015)
- University of Brasilia, Brazil (July 2015)
- Federal University of Rio de Janeiro, Brazil (July 2015)
- Federal University of Rio de Janeiro, Brazil (Sept. 2015)
- IT Mexicali, Mexico (October 2015)
- Trinity College Dublin, Ireland (March 2016)
- University of Brasilia, Brazil (May 2016)
- IT Mexicali, Mexico (October 2016)



Evaluation and reflection

Dynamic spectrum access & wireless signalling – Use case

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Questionnaires used to inquire student perception (Qualitative)

- Surveymonkey.com (anonymize)
- Google forms

SurveyMonkey

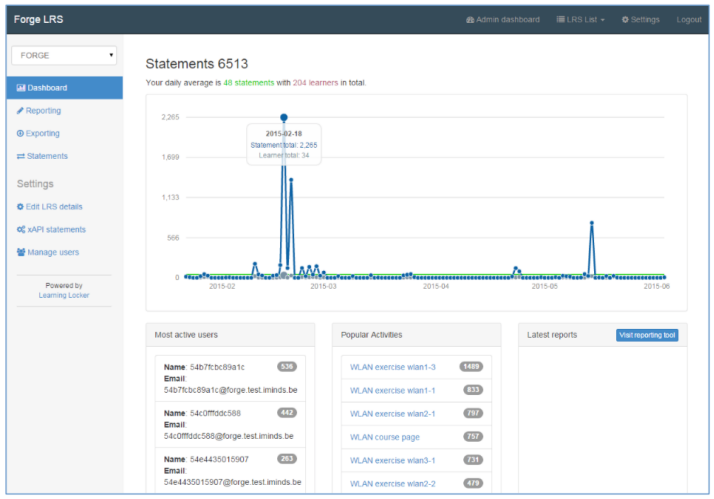
Google Forms

	Strongly disagree	Moderately disagree	Neutral	Moderately agree	Strongly agree	Total	Weighted Average
The lab experiments helped you to understand the concepts taught in the lecture.	0.00% 0	3.85% 1	0.00% 0	34.62% 9	61.54% 16	26	4.54
The interface (web or command-based) reduced the difficulty of the lab.	0.00% 0	3.85% 1	3.85% 1	23.08% 6	69.23% 18	26	4.58
You were always aware that you were performing real experiments using network equipment located in other facilities around the world.	3.85% 1	0.00% 0	3.85% 1	11.54% 3	80.77% 21	26	4.65
The experimentation helped you to self-assess your progress in the course.	3.85% 1	3.85% 1	0.00% 0	34.62% 9	57.69% 15	26	4.38
You would use the testbed facility in the future, if you have access to it.	3.85% 1	0.00% 0	0.00% 0	7.69% 2	88.46% 23	26	4.77

Learning analytics integrated into the widgets xAPI (Quantitative)

- Learning Locker

LEARNING LOCKER



"Deploying Learning Analytics for Online Scientific Experimentation", Alexander Mikroyannidis, Aitor Gomez-Goiri, John Domingue, Christos Tranoris, Daan Pareit, Jono Vanhie-Van Gerwen, and Johann M. Marquez-Barja. 5th Workshop on Awareness and Reflection in Technology Enhanced Learning (ARTEL 2015), satellite workshop of the 10th European Conference on Technology Enhanced Learning. pp 105-112. September, 2015. Toledo, Spain

Research &

EXPERIMENTATION

& Education

Remote experimentation in your pockets…

Guilles Lambert

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Thank you

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