MSc Curriculum in Resilient Computing*

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*Co-operative work in the frame of EU NoE ReSIST

http://www.resist-noe.org/

Why a curriculum on Resilient Computing

Resilience (for computing systems and information infrastructures): the persistence of the ability to deliver service that can justifiably be trusted, when facing functional, environmental or technological evolutionary changes

Evolutionary changes:

- **Foreseen**, e.g. new versioning
- **Foreseeable**, e.g. advent of new hardware platforms
- **Unforeseen**, e.g. drastic changes in service requests or new type of threats

- **Short term**, e.g. seconds to hours, as in dynamicity or mobility
- **Medium term**, e.g. hours to months, as in new versioning or reconfigurations
- **Long term**, e.g. months to years, as in reorganizations

Computing in the future

Table 1. Examples of Pervasive Computing

• Wearable Computers	• Smart Classrooms
• Wearable Keyboards	• Enhanced Learning Environments
• Smart Homes	• Telematics
• Active Badges	• GPS-equipped Automobiles
• Active RFID tags	

Table 2. Two Alternate Futures

Future Given Current Trends	Trustworthy Future
Spam	Hassle-free systems
Identity theft	User-controlled privacy
Network outages	Self-aware networks
Malware	Self-adjusting networks
Frequent manual intervention	Self-healing networks
Unchecked abuses of laws and rights	Balanced regulation and law enforcement

Four Grand Challenges:

1. **Eliminate Epidemic Attacks by 2014**
2. **Enable Trusted Systems for Important Societal Applications**
3. **Develop Accurate Risk Analysis for Cyber-security**
4. **Secure the Ubiquitous Computing Environments of the Future**

Some examples of recent resilience problems

- **"Over the past five years, high profile IT difficulties have affected the [UK's] Child Support Agency, Passport Office, Criminal Records Bureau, Inland Revenue, National Air Traffic Services and the Department of Work and Pensions, among others"**

  S. Pearce. Government IT Projects, Report 200, Parliamentary Office of Science and Technology, 7 Millbank, London, 2003.

- **The French Insurer's Association estimates the yearly cost of computer failures to be 2 B Euros, of which slightly more than half is due to malicious faults (e.g. by hackers and corrupt insiders)**

  https://www.clusif.asso.fr/fr/production/sinistralite/index.asp

- **"At 03.25hrs on Sunday 28 September 2003, the Italian power system experienced a power failure across all of Italy because of an inadequate SCADA (supervisory control and data acquisition) systems… The electricity supply to Rome was not restored until late afternoon and the remainder by late evening"**

  Report of Joint Energy Security of Supply Working Group - http://www.dti.gov.uk/energy/jess/blackout_note.pdf

- **"Nearly 10 million people in the US suffered from some kind of on-line fraud last year … the total cost was $1.2bn"**

  Stated by Gartner at RSA Conference, February 2005 - http://www.vnunet.com/news/1161375

- **"Law enforcement agencies in the United States and overseas recently disrupted an on-line organised crime ring that spanned eight U.S. states and six countries … 7 million credit card numbers had been stolen by the crime ring, costing consumers and credit card companies around $4.3 million"**

  Ralph Basham, Director of the U.S. Secret Service - http://www.reuters.com/newsArticle.jhtml?type=topNews&storyID=7667789

- **"Mobile devices such as PDAs and cell phones are the new frontier for viruses, spam and other security threats … 70 percent of all email traffic on the Internet is spam … The number of known viruses grew by 28,327 in 2004 (for a running total of 112,438 known viruses) an increase of 25 percent from 2003"**

  IBM 2004 Global Business Security Index Report - http://www.ibm.com/news/be/en/2005/02/09.html

- **"On 17 Mar 2005 the UK's National Hi-Tech Crime Unit reported a (foiled) attempt to steal £220m from the London offices of the Japanese bank Sumitomo Mitsui, by criminals who attempted to transfer the money electronically after hacking into the bank's systems"**

  BBC News http://news.bbc.co.uk/1/hi/uk/4356661.stm

What about software ?

- In 1995, The Standish Group reported that the average US software project overran its budgeted time by 190%, its budgeted costs by 222%, and delivered only 60% of the planned functionality. Only 16% of projects were delivered at the estimated time and cost, and 31% of projects were cancelled before delivery, with larger companies performing much worse than smaller ones. Later Standish Group surveys show an improving trend, but success rates are still low

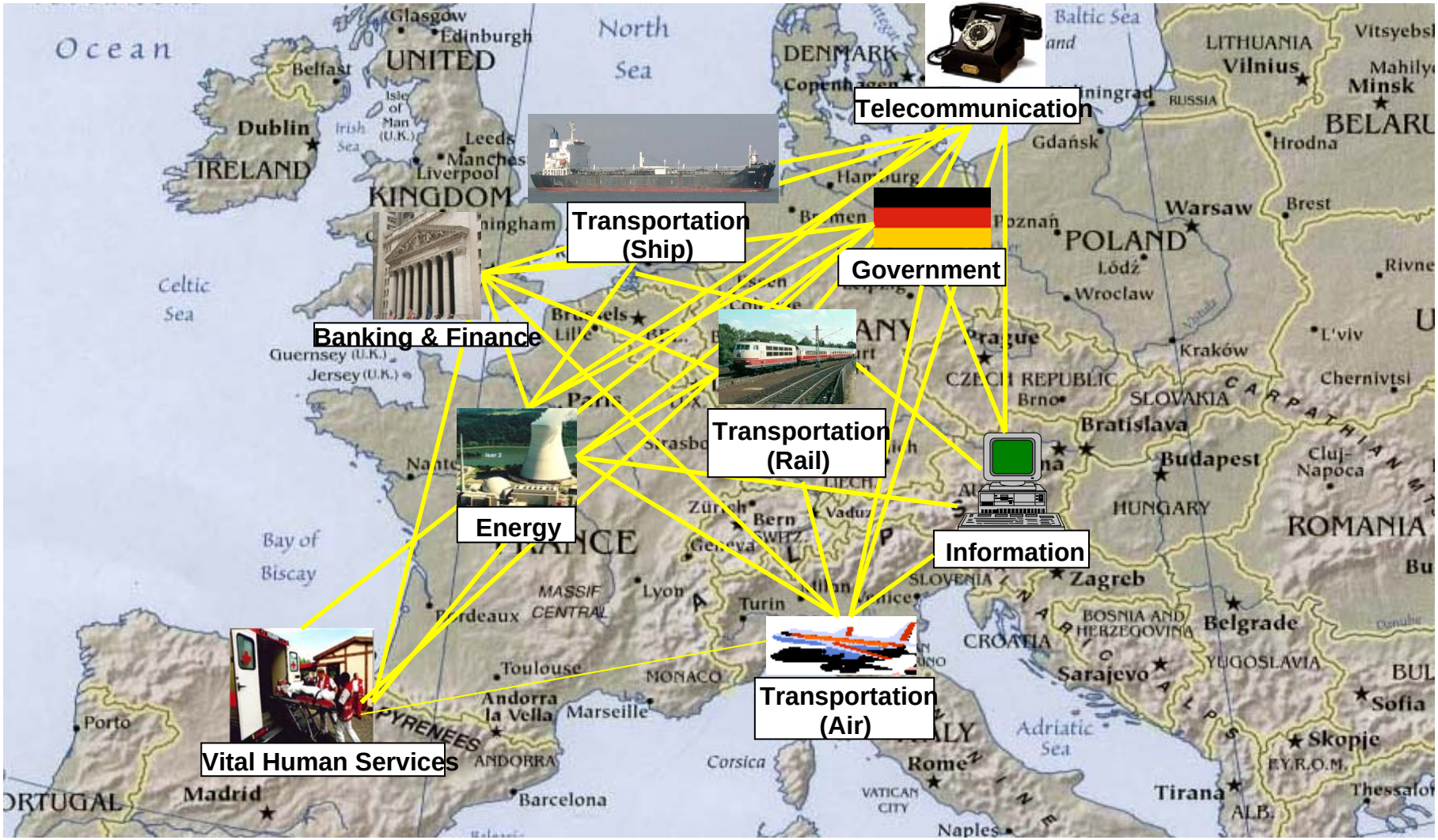
- A UK survey, published in the 2001 Annual Review of the British Computer Society showed a similar picture. Of more than 500 development projects, only 3 (three!!!) met the survey's criteria for success.

- In 2002, the annual cost of poor quality software to the US economy was estimated at $ 60B [NIST, 2002]

Risks, novel problems and need for integration

Class of Applications	Present or Potential Risks	Novel Problems	Need for Integration
Critical Utility Infrastructures (e.g. power distribution)	Black-outs (e.g. Italy 29/09/2003)	-Escalating and Cascading failures - Human Interaction	- New fault types - Interdependencies - Resilience for survivability
E-commerce (e.g. online auctions – eBay)	Frauds (several reported)	-Trusted identity management of dynamic sellers/buyers	- Identity mngmt. - Security - Legal issues
Personal digital devices	Potential catastrophe on a large-scale basis (not yet reported)	- “Common mode” failures affecting a very large number of untrained users at the same time	- Human interface - Public awareness - Societal issues

Complex systems need to be correct and resilient



- Pervasive and ubiquitous computing - always on-line
- Open dynamic heterogeneous interconnected system
- Sensitive personal information
- Untrained users - often risks unaware

- "Panic inducing" malicious faults
- "Huge multiplicity common mode" accidental faults

Catastrophic failure

Ambient Resilience:

a global view of the concept of joint dependability and security, which encompasses not only the technological aspects but includes inter and multi-disciplinary fields that span over ergonomics, usability, education, sociology, law and government.

Why "Ambient Resilience" ?

- **New threats** have to be analyzed, studied and modeled
- **New fault types** have to be analyzed, studied and modeled
- Design methodologies have to be studied for **designing under uncertainty**
- **A user-centered design** approach, like design for usability, has to be applied
- **Architectural frameworks** are needed for adapting functional and non-functional properties while at least providing guarantees on how dependably they are adapting
- Identification of **proper resilience scaling** technologies to deal with **trustable and survivable provision of services** based on evolving systems and infrastructures
- **New modeling and simulation means and tools** are needed for complex interdependencies, for system evolution, for evaluation of combined measures and of security vulnerabilities

Focus and priorities

- **Understanding new risks and threats** arising from the dynamic and evolutionary nature of the systems and their environments.
- **Understand the boundary-less nature of systems** and their failure behaviour with a need for modelling, data collection, experimentation, assessing systemic risks, and the possibility of emergent behaviour and surprise.
- Developing existing resilience technologies to **deal with increased scale and complexity and criticality** (telecoms, embedded, smart cards) – **emphasis on critical components.**
- Developing theories, methods, tools for the design, development and evaluation of AmI systems and existing systems in the changed threat environment – **emphasis on composability.**
- Understanding and assessing trust, risk and responsibility, predicting trust relationships and developing methods for **users – oriented dependability risk assessments.**
- Dependability of **meta-data.**
- **Developing a multi-disciplinary resilience community** by empirical studies, joint program of work, addressing fundamental concepts. Does not exist at the moment.

ReSIST NoE
Resilience for Survivability in IST

Information Society Technologies

SIXTH FRAMEWORK PROGRAMME

Rationale

(Reasonably) known:
High dependability and security
for safety-critical or availability-critical systems

- Avionics, railway signalling, nuclear control, etc.
- Transaction processing, back-end servers, etc.

Continuous complexity growth
Large, networked, evolving, applications
running on open systems, fixed or mobile

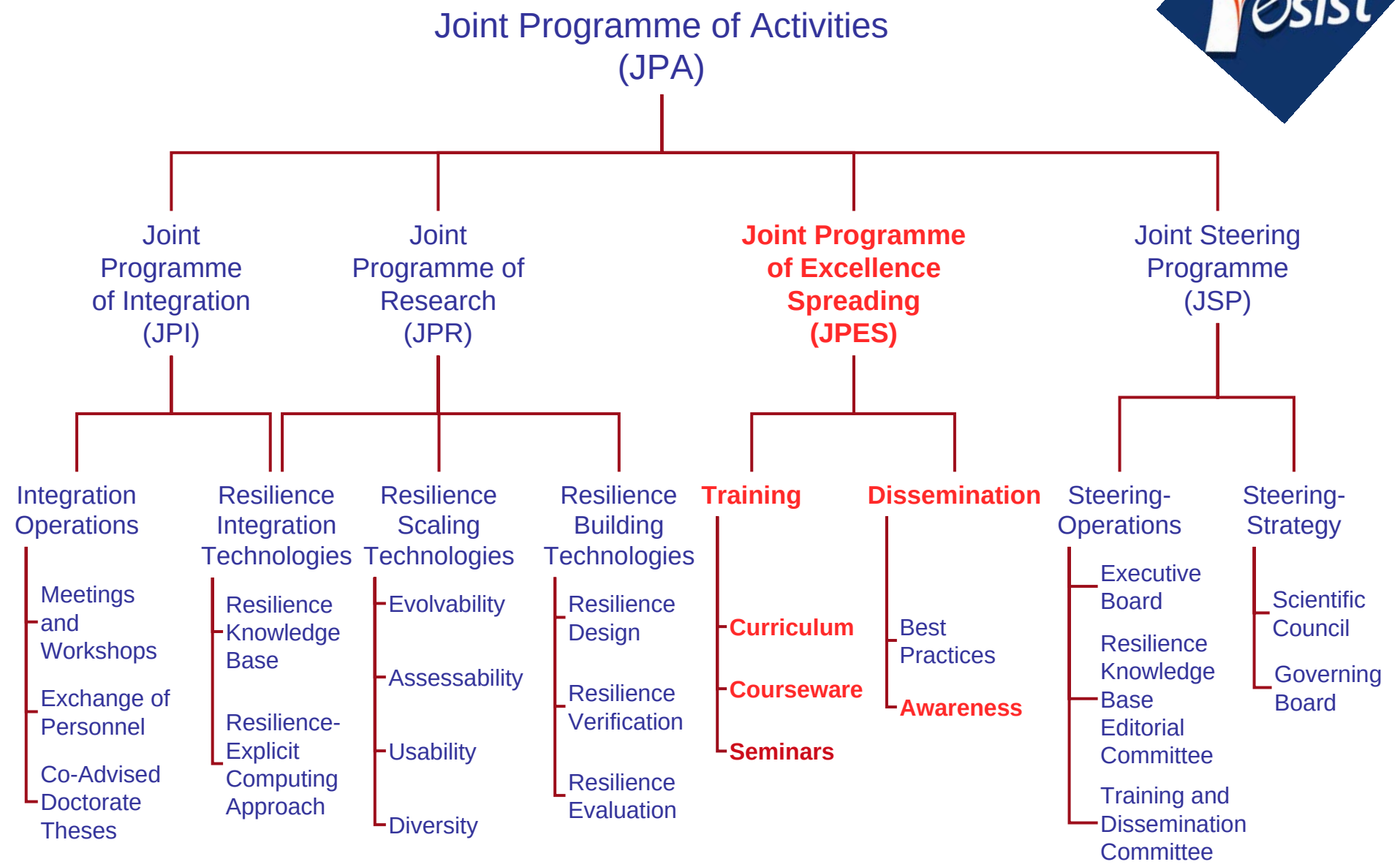
Scalability of Dependability
Beyond rigorous functional design, provision of
Resilience for Survivability,
wrt accidental and malicious threats

Logic

Partners

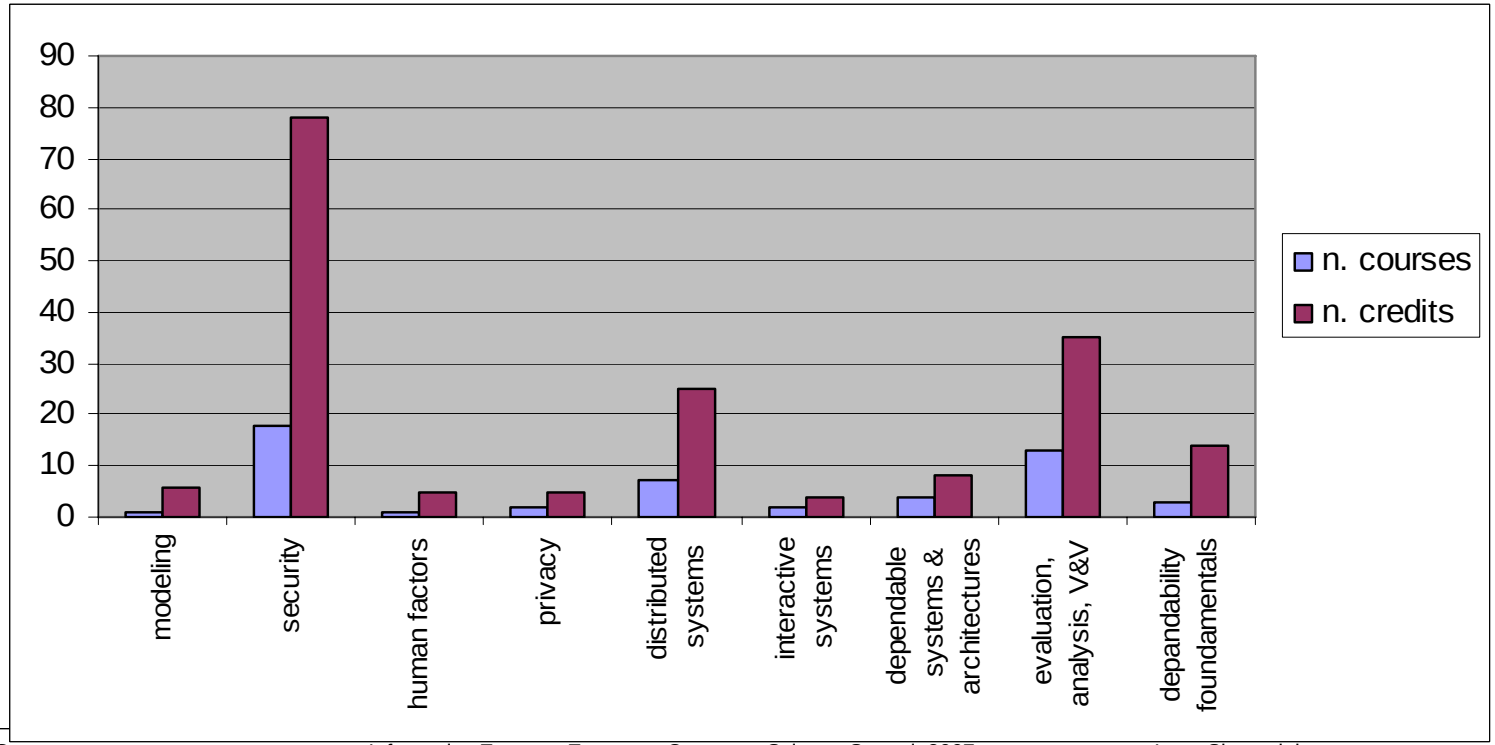
Budapest U
City U
Darmstadt U
DeepBlue
Eurecom
France Telecom R&D
IBM Zurich
IRISA
IRIT
LAAS-CNRS (Coord.)
Lisbon U
Newcastle U
Pisa U
QinetiQ
Roma-La Sapienza U
Southampton U
Ulm U
Vytautas Magnus U

Joint Programme of Activities insight



	n. courses	n. credits
modeling	1	6
security	18	78
human factors	1	5
privacy	2	5
distributed systems	7	25
interactive systems	2	4
dependable systems & architectures	4	8
evaluation, analysis, V&V	13	35
dependability fundamentals	3	14
TOTAL	***51***	***180***

Overview
at 10/10/2006



Curriculum rationale

To move from the usual application-driven MSc curricola (like MSc in embedded systems or web-based systems, etc.)

To identify a MSc curriculum where, in the first year, the focus is on advanced fundamental invariants (application independent) that can provide students with a solid updated theoretical knowledge for dealing with resilience

To specialize, in the second year, on applications of such knowledge on real projects in selected application tracks with strong connection with productive world

To remove the gap between what is *known* and what is *used:*

From Best Practices ⟶ to Methodical Scientific Approach

Curriculum aims

- To equip students with the skills and knowledge required to develop and assess secure and dependable computer-based systems
- To provide a qualification enhancing employment prospects in resilient computing
- To develop research skills
- To develop and improve key skills in written and oral communication and in teamwork
- To develop and improve skills in using the literature and information technology resources relevant to resilient computing
- To encourage the development of creativity skills
- To develop skills in critical assessment, analysis and storage of information
- To provide a curriculum which meets the requirements of appropriate professional bodies, thus providing a basis for further professional development and lifelong learning
- To address the relevant professional, legal and ethical issues relevant to the development, assessment and maintenance of resilient systems
- To provide an international perspective on developments in computer resilience.

Curriculum organization

1st Year

- **1st semester: Basics and Fundamentals (30 ECTS)**

Courses:

- **Advanced Probability and Statistics**(6 ECTS)
- **Cryptology and Information Security** (6 ECTS)
- **Logic in Computer Science** (6 ECTS)
- **Advanced Graph Theory** (3 ECTS)
- **Human Factors, Human and Organizational Behavior** (3 ECTS)
- **Fundamentals of Real-Time Systems** (3 ECTS)
- **Fundamentals of Dependability** (3 ECTS)

- **2nd semester: Methods, Techniques and Tools (30 ECTS)**

Courses:

- **Computer Networks Security** (6 ECTS)
- **Fault and Intrusion-Tolerant Distributed Systems and Algorithms** (6 ECTS)
- **Dependability Evaluation of Computer Systems** (6 ECTS)
- **Testing, Verification and Validation** (6 ECTS)
- **Usability and User Centered Design for Dependable and Usable Socio-technical Systems** (6 ECTS)

1st semester scheduling

Advanced Probability and Statistics	
Cryptology and Information Security	
Logic in Computer Science	
Advanced Graph Theory	**Human Factors, Human and Organizational Behavior**
Fundamentals of Real-Time Systems	**Fundamentals of Dependability**

2nd semester scheduling

Computer Networks Security
Fault and Intrusion-Tolerant Distributed Systems and Algorithms
Dependability Evaluation of Computer Systems
Testing, Verification and Validation
Usability and User Centered Design for Dependable and Usable Socio-technical Systems

3rd semester: Projects (in cooperation with industry on specific appl. fields) (30 ECTS)

Courses (common to all application tracks)

- **Management of Projects** (3 ECTS)
- **Fault Tolerant Middleware- based Systems** (3 ECTS)
- **Software Reliability Engineering** (3 ECTS)

Application track: **Telecom.**

Courses (specific for this track):

- **Resilience of Protocols and Architecture** (3 ECTS)
- **Resilience of Mobile Applications** (3 ECTS)

Application track: **Safety critical Systems**

Courses (specific for this track):

- **Development Process and Standards for Safety critical Applications** (3 ECTS)
- **Architectural Issues and Examples of Systems** (3 ECTS)

Application track: **e-Business**

Courses (specific for this track):

- **Resilience of SOA and Web-based Applications** (3 ECTS)
- **Damage Tolerance in Large scale Systems** (3 ECTS)

Common to all Application tracks:

- **Project in cooperation with Industry** (9 ECTS)
- **Space for additional Courses** (6 ECTS)

4th semester: Master's Thesis and Dissertation (30 ECTS)

- **Specific Courses and Seminars** (3 ECTS)
- **Preparation and Presentation of the Thesis** (27 ECTS)

Curriculum Pre-requisites

- **Discrete Mathematics**
- **Calculus**
- **Basic Computer and Network Architectures**
- **Programming and Data Structures**
- **Basics of Operating Systems**
- **Basics of Software Engineering**
- **Basics of Probability and Statistics**

Contributions welcome !

- **Review first year courses and their content**
- **Propose courses and appl. tracks for second year**
- **Identify existing support material for all courses**

Means for contributing:

- **Through the curriculum forum at ReSIST web portal**
  http://www.resist-noe.org/
- **Through a dedicated Consultation Panel (under construction) at:**
  http://resist.isti.cnr.it/home.php

Events of interest:

- **Professoral Seminar on Sept. 2-4, 2008 to inform on ReSIST findings and discuss with interested academics of the best way of disseminating this knowledge**
- **Dedicated WSs during 2008 on the MSc Curriculum on Resilient Computing**

Persons interested to be informed:

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