ISRAEL AEROSPACE INDUSTRIES LTD

Starting a New Embedded Systems Specialty

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A Joint Industry - Academia View

08.10.2015

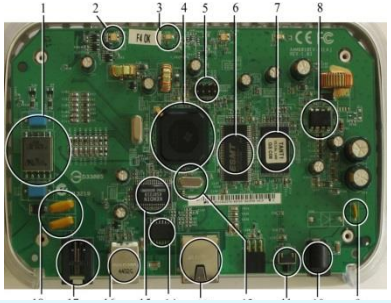
Topics

- Quick review: ECS and CPS
- Israel Aerospace Industries overview
- Skills required for IAI's ECS engineers
- Market competition over skilled engineers
- The HIT solution to bridge the Gap at undergraduate level
- Open discussion and dilemmas:
  - An example: functional security, Process or SIL focus?
  - The naming of Cats: how to call a B.Sc.?
  - Graduate studies dilemma: which M.Sc. degree?

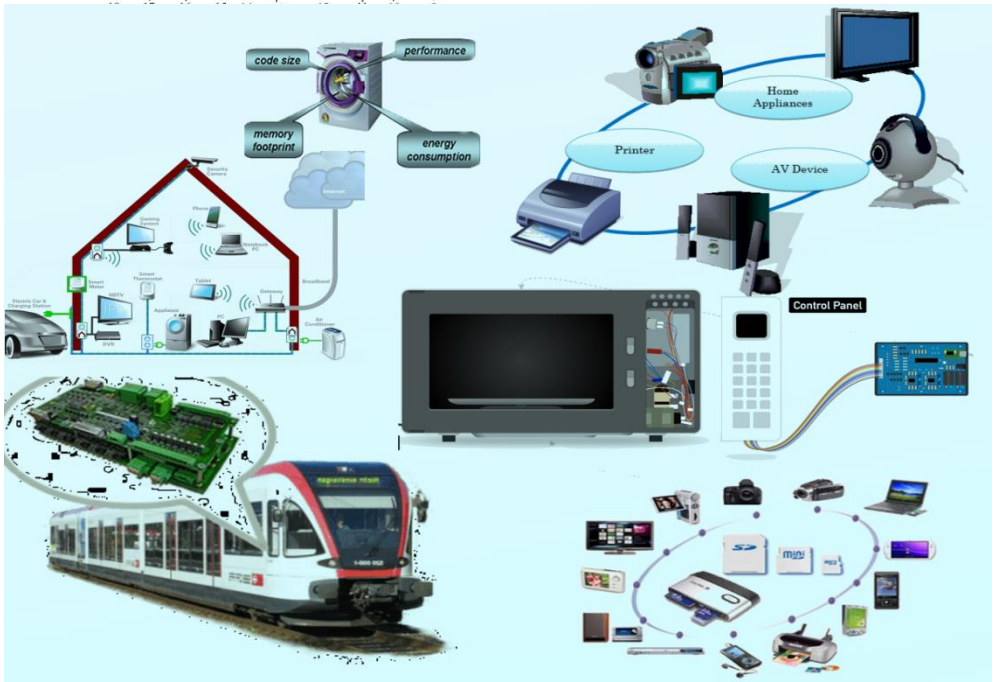
What are Embedded Computer Systems?

An **embedded system** is a computer system with a dedicated function **within a larger mechanical or electrical system**, often with **real-time** computing **constraints**. It is *embedded* as part of a complete device often including hardware and mechanical parts. **Embedded systems** control many devices in common use today.

(Wikipedia)



ADSL modem/router



Definitions (1/2) – Embedded Systems

Embedded systems can be defined as information processing systems embedded into enclosing products such as cars, telecommunication or fabrication equipment. Such systems come with a large number of common characteristics, including real-time constraints, and dependability as well as efficiency requirements

P. Marwedel, in "Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems", 2010

Definitions (2/2) – ECS vs CPS

Cyber-Physical Systems (CPS) are **integrations of computation, networking, and physical processes**. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa.

http://cyberphysicalsystems.org/

Directions in Cyber Physical Systems

Orchestrating networked computational resources with physical systems

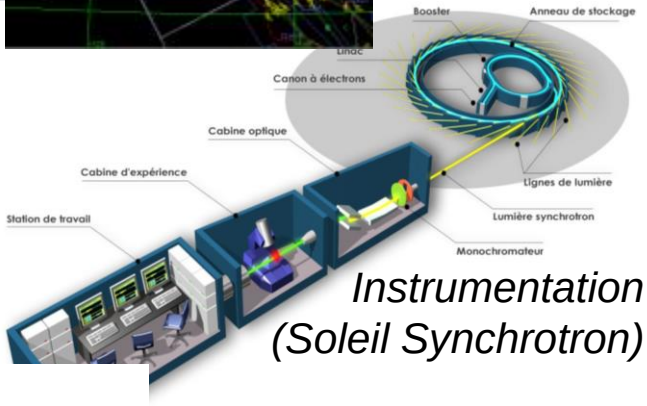
Slide by E. Lee, WESE 2009 Keynote

Avionics

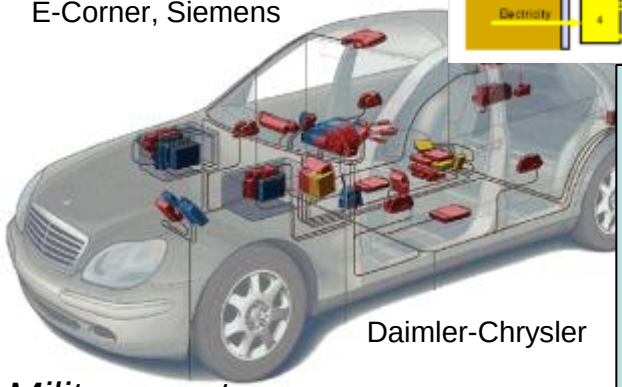
Automotive

E-Corner, Siemens

Telecommunication



Instrumentation (Soleil Synchrotron)



Daimler-Chrysler

Power generation and distribution

Courtesy of General Electric

Military systems:

Courtesy of Doug Schmidt

IAI - A World-Leading Aerospace Company

- Employees: 15,000
- 6000 Engineers
- 2014 results:
  - Sales: $3.83B
  - Backlog: $9.1B
  - IR&D: $165M
- Reporting company
- IAI Global company – over 74% export

- Special mission and early warning aircraft
- Unmanned air vehicle systems
- Radars and electronic intelligence
- Strategic defense systems
- Missiles and loitering weapons
- Passenger-to-freight aircraft conversions
- Satellites and space systems

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Cyber Physical and Systems of Systems development at IAI

Some Examples

Unmanned Aerial Vehicle (UAV) Systems

UAV C3 Systems

- Connectivity
- Command & Control Stations
- Training Simulators

- Joint Ops
- Fully automatic takeoff, flight & landing

MALE


Heron TP


Heron 1

TACTICAL


Searcher


Rotary


Panther VTOL

SMALL


Mosquito


ETOP


Ghost

Israel's National Space House

TECSAR 2
2014

Optsat 3000
2014

Amos 4 2013

Venus 2013

Shavit
Launcher

Ground Stations

Ofeq 9
Launched 2010

Robotics

Robotic Engineering Equipment

Unmanned Ground Vehicle (UGV)

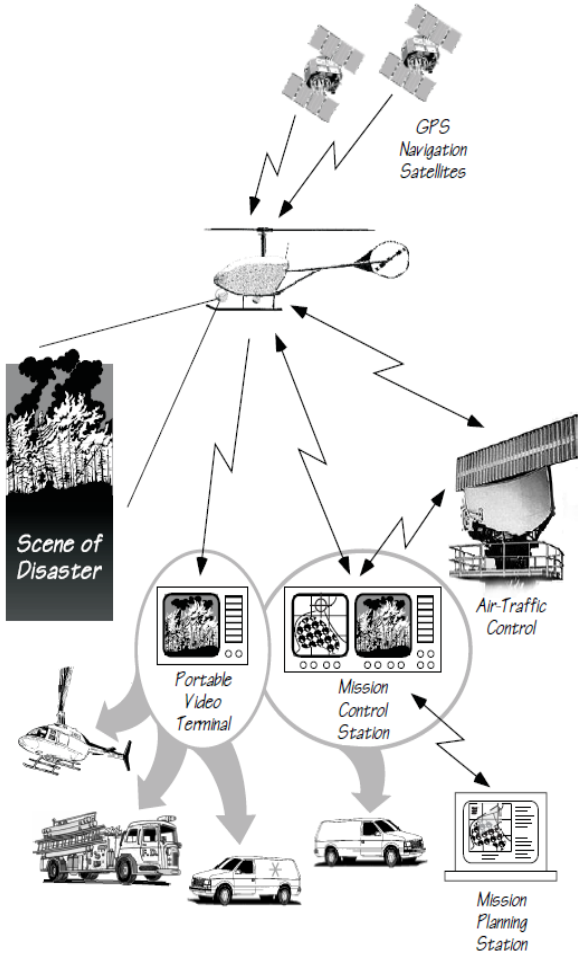
GNIUS

Skills required for IAI's ECS Engineers

Expertise in HW , SW and firmware:

- Knowledge of several SW languages (C, C++, Python, Java,….)
- Knowledge of HDLs (Verilog, VHDL…)
- Previous exposure to development boards (Intel, Freescale, ARM, Altera, etc.)
- Knowledge of Real Time operating systems (open-source and commercial)
- Experience in Real Time Systems development
- Modeling, modeling, modeling…….and

A passion for Cyber Physical Systems development



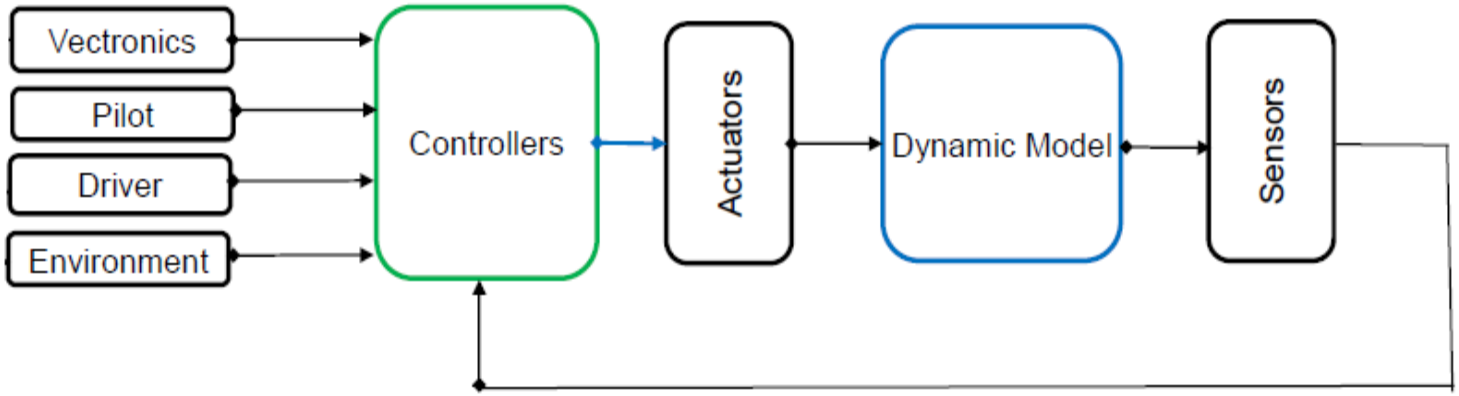
The Taxibot Development Environment and its Tools

TAXIBOT – Robotic Taxi for Passenger Planes

- Saving fuel, pollution & FOD by taxiing aircraft to takeoff position by a robotic tow vehicle, controlled by the aircraft pilot, instead of self-powered taxi
- Aircraft starts engines **shortly before entering runway**
- Mechanism reduces front wheel strut braking forces

Taxibot MBD: Model In the Loop (MiL)

- Model In the Loop is a full test environment:
  - **Vectronics:** models of inputs for force envelopes etc.
  - **Pilot:** models of inputs for steering and braking.
  - **Driver:** models of inputs for emergency button etc.
  - **Environment:** model for wind velocity and direction.
  - **Controllers:** contains full control software.
  - **Actuators/sensors:** models include dynamics, signal conditioning, delays, etc.



Development Environment

- Target: ELTA CMCPA
- OS: VxWorks 6.6.4.1 Cert.
- Windriver Workbench 3.3
- Modeling tools:
  - Simulink
  - Stateflow
  - Realtime workshop
  - Other Mathworks products…
- Configuration Management: Clearcase UCM
- Requirements Management : Doors
- Software Coverage: IBM Rational Test RealTime (RTRT).
- Tests Management, Changes Tracking, Formal reviews: HP Quality Center (QC)
- Lab Simulation: HIL(dSpace Hardware In the Loop) – implemented using Simulink Dynamic model using real time communication HW

Competition for University Graduates

- Industry in Israel is extremely active in all range of areas of embedded systems, e.g.:
  - Advanced SoC development at technologies' leading edge
  - Communication systems and components
  - Medical devices
  - Aerospace and defense systems
  - START UPs in a vast variety of creative solutions

These industries require a large amount of embedded systems engineers each year. A quick scan of the "Employment EMBEDDED" term, in Google introduces no less than 100 new jobs in embedded systems engineers requested each month in Israel.

The HIT Initiative

Undergraduate ES Concentration Joint Program:

- **Elec. Eng.**
- **Computer Science**
- **Applied Maths**

Started Oct 2014

The HIT ES Concentration Courses

רשימת הקורסים במסלול

קורסי ליבה

1. אלגוריתמים ומבני נתונים (כולל מעבדה מתקדמת לתכנות חדש)
2. מערכות הפעלה זמן אמת
3. אפיון ותכנון מערכות משובצות מחשב - חדש
4. מבוא לארכיטקטורת מחשבים

קורסי בחירה

1. ראיה ממוחשבת במערכות זמן אמת
2. שפות תיכון חומרה
3. CYBER במערכות משובצות - חדש
4. כלי פיתוח למערכות משובצות מחשב - חדש
5. מערכות אירועים בדידים - חדש

מעבדות:

מעבדה לתיכון רכיבי מחשב

מעבדה למערכות משובצות מיקרופרוססורים ו-FPGA

מעבדה למערכות זמן אמת משובצות מחשב - חדש

11

מכון טכנולוגי חולון
איכות ומצוינות

The HIT ES Concentration Courses

- Core Courses:
  - Algorithms and data structure
  - RT Operating Systems
  - ECS Specification and development
  - Computer Architecture
  - HDL
- Elective courses examples:
  - ECS security, Computer Vision, Automatic Generation tools, etc.
- Labs (2 mandatory): RT ECS design, integrated mps & fpga design, computer components design

Focus: Model Based ES Engineering

- **Example: Specification and development of Embedded Computer Systems - Course 50223**
- **Course objectives:**

  Exposure to the engineering tasks involved in the systematic specification and development of embedded computer systems (ECS) within the overall development of complex Cyber Physical Systems (CPS). The course includes an overview of the development processes and the main factors to achieve product quality with in-depth technical lectures on definition of requirements, analysis, design and ECS verification and testing.

Part 1: ES architecture within a CPS

HW-SW architecture

- The system in its environment
- The analysis process
- Basic functional models and specification
- The need for Object Based Analysis
- The Generic Model of Embedded Computer Systems and Their Software
- System Conceptual components
- Conceptual vs. design architecture
- Basic decomposition steps
- Criteria supporting decomposition
- Practical decomposition considerations

Part 2: Specification and Modeling

Functional and Behavior Modeling

- ES functionality modeling - Scenarios
- Hierarchical decomposition of flows
- Signal flows, Process flow & variable characterization
- Identification of functional capabilities of components
- Dynamics Modeling: definition of operating modes and states of embedded systems
- The mathematical formalism of STATECHARTs
- Defining systems operating modes: the working method
- Analysis and timing of transitions
- Real-time behavior specification and analysis
- Examples and exercise (ATM, Remote Medical Diagnostics, Automatic Parking System)

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Open discussion: some dilemmas for academia

Functional safety standards focus on Electrical, Electronic and Programmable Systems (E/E/PS).

Dilemma 1: What to teach?

Avionics

DO-178B
Certification Standard for Avionics

DO-254
Design Assurance Guidance for Airborne Electronic Hardware

DO-160F
Environmental Cond… and Test Proce… Airborne E…

Functional Safety … 61508)

IEC 615…

… 60601-1
Medical electrical equipment General requirements for basic safety and essential performance

… 26262
Functional Safety in Automotive Electronics

EN 5012x
EN 50128 / EN 50129
Rail transport

IEC 60880-2
Nuclear Power

Medical Devices

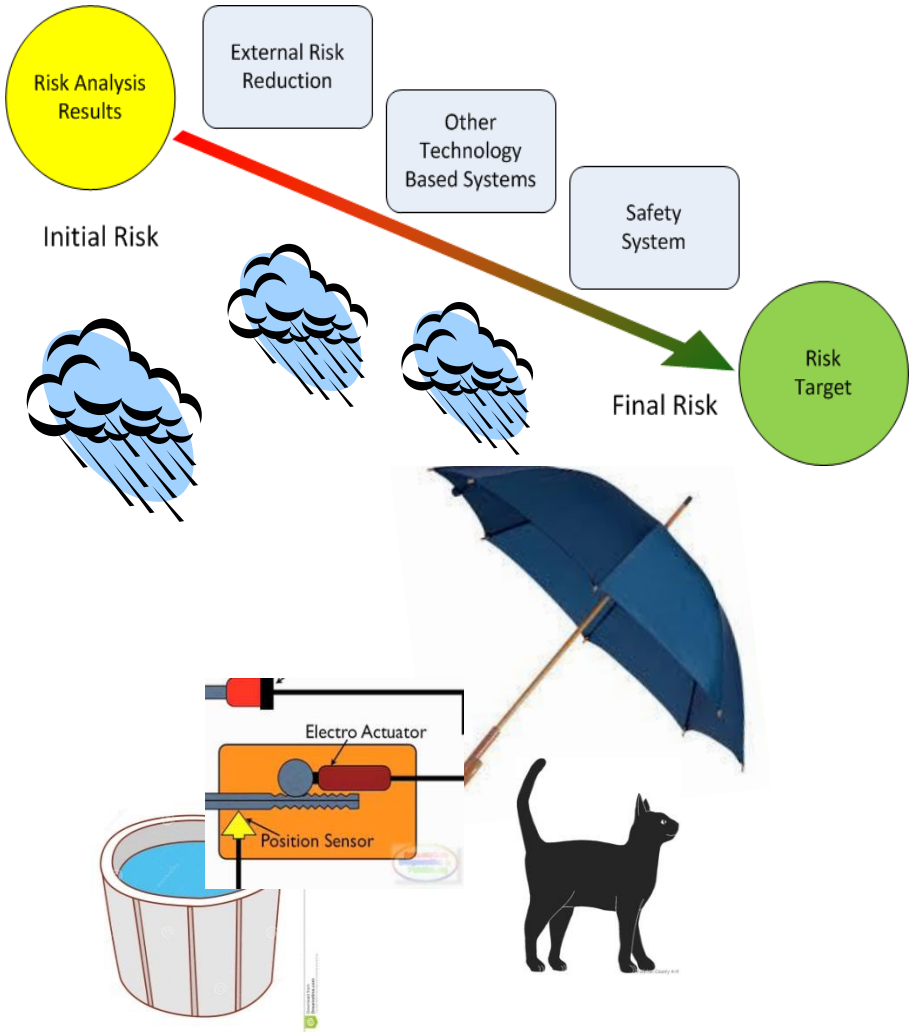
FDA-21 CFR
Medical Records

IEC 62304
Medical Devices

Safety Integrity Levels (SIL) - IEC 61508

- Assignment of SIL is an exercise in risk analysis where the risk associated with a specific hazard, that is intended to be protected against by a **E/E/PE Safety-related system** is calculated without the beneficial risk reduction effect of the **E/E/PE**.
- The "unmitigated" risk is then compared against a **tolerable risk target**.
- The difference between the "unmitigated“ risk and the tolerable risk must be addressed through risk reduction.

SIL Level and Risk reduction



SIL 0 - no safety requirement for the function **SIL A** - risk reduction of less than a factor of 10 required from the safety function (SF)

SIL 1 – Risk without SF, 10 times more than tolerable target

SIL 2 - Risk without SF, 100 times more than tolerable target

SIL 3 - Risk without SF, 1000 times more than tolerable target

SIL 4 - Risk reduction by a factor of ten thousand **– Is the risk without the Safety Function that large?**

Aircraft Safety

Focus is on Airborne SW and HW Systems Certification

DO 178 C – Software Focus is Process

Level	Failure condition	Obje
A	Catastrophi	
B	Haz	
C		
D		5
		0

What should we teach, SIL assessment and reduction or Process?

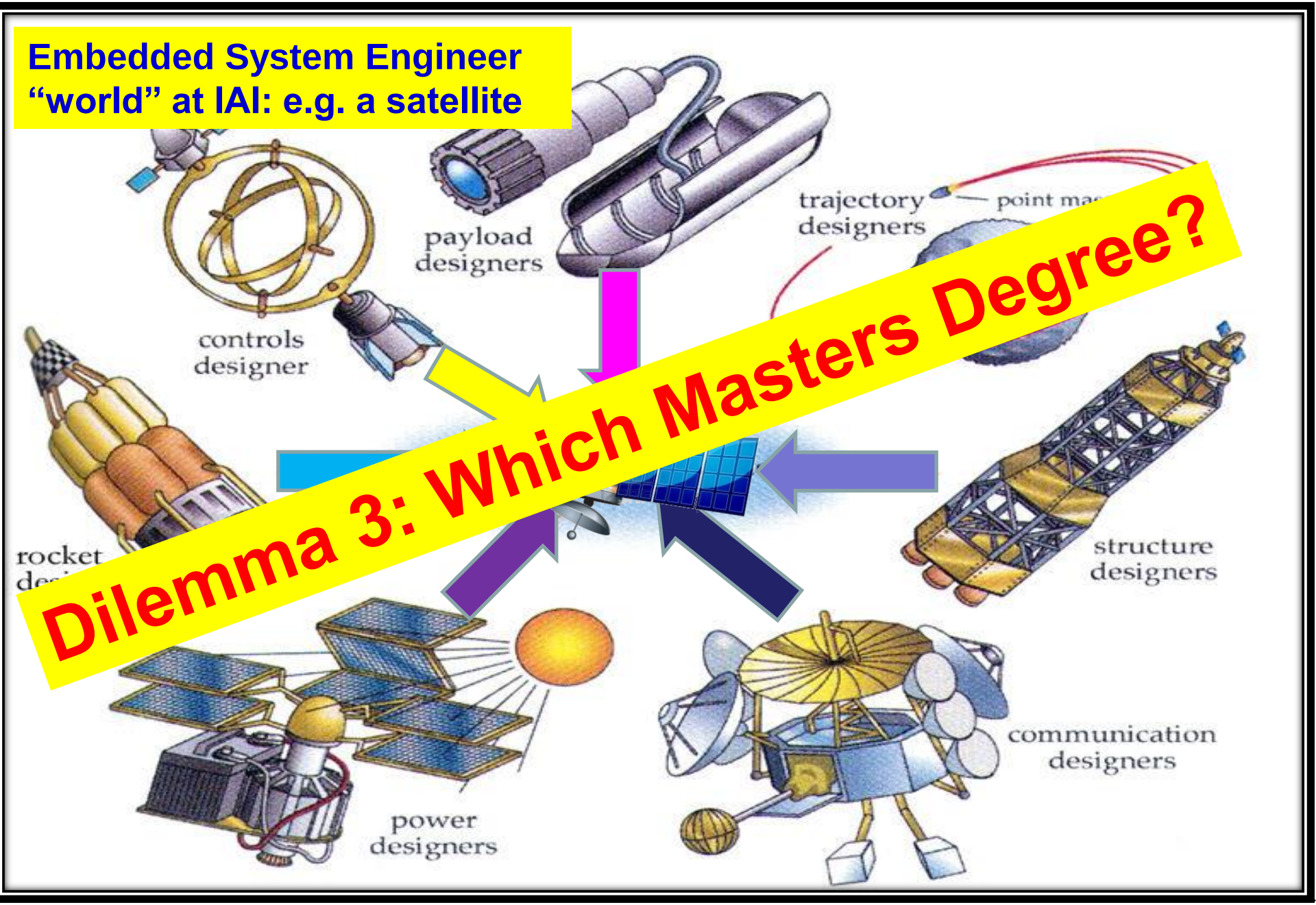
Any commands, controls, and monitors safet functions should receive the highest DAL - Level A

The naming of Cats: how to call a B.Sc.?

- Embedded Syste
- Cyber Ph ering
- C gineering

Dilemma 2: what is attractive to industry, to students, to academic regulators?

Embedded System Engineer "world" at IAI: e.g. a satellite



Dilemma 3: Which Masters Degree?

The Masters Degree Dilemma

- What type of graduate students are needed in industry ?
- How long the training?
- Masters in Embedded Systems or Systems Engineering:
  - MSc with Thesis
  - ME with final project

Thank you