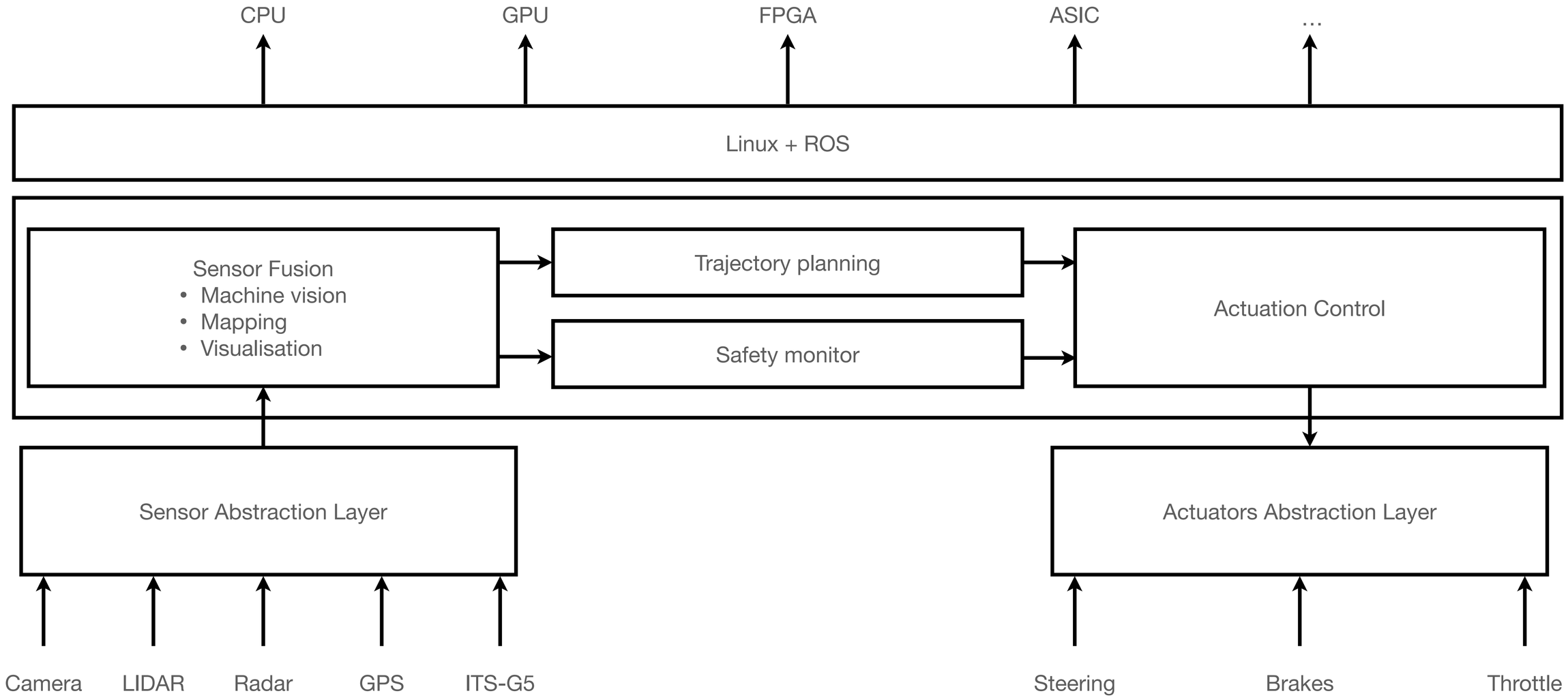
# Vehicle Automation

## Flanders MAKE

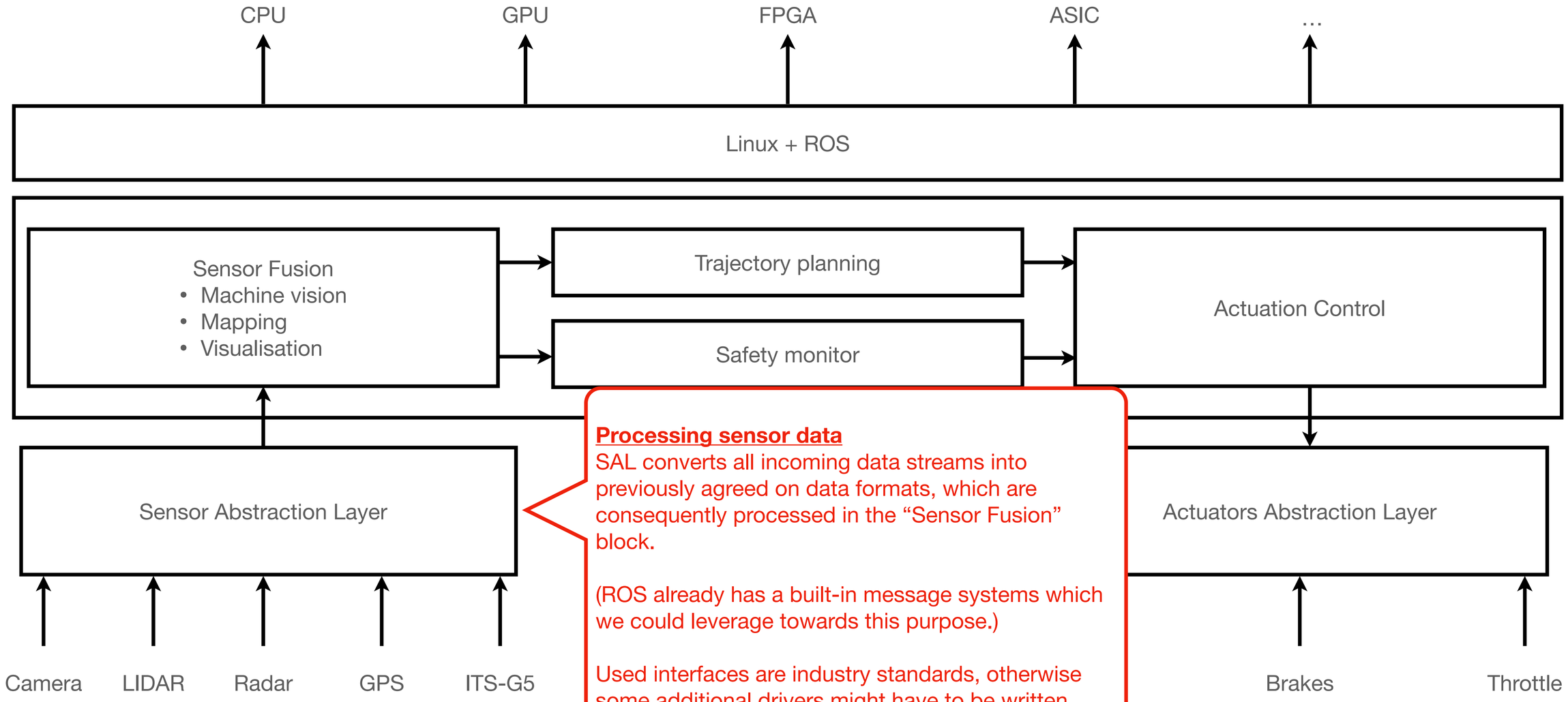
**Maksim Nesterenko - 1/02/21**

1. What software architecture would you propose
    a. in order to process all sensor data,
    b. with the need for sensor fusion to increase probability detection and
    c. to support modularity and scalability e.g. for future enhancements and use within multiple projects?

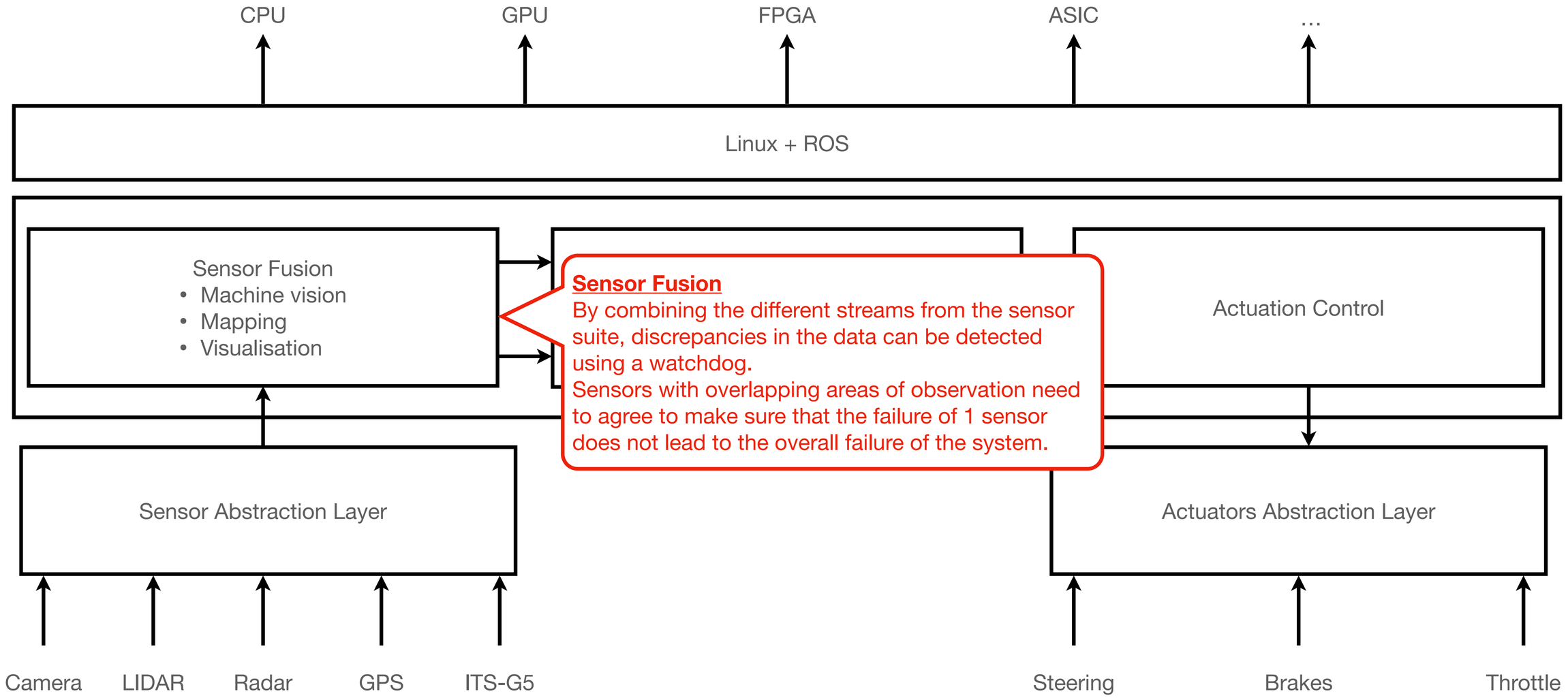
# Software Architecture



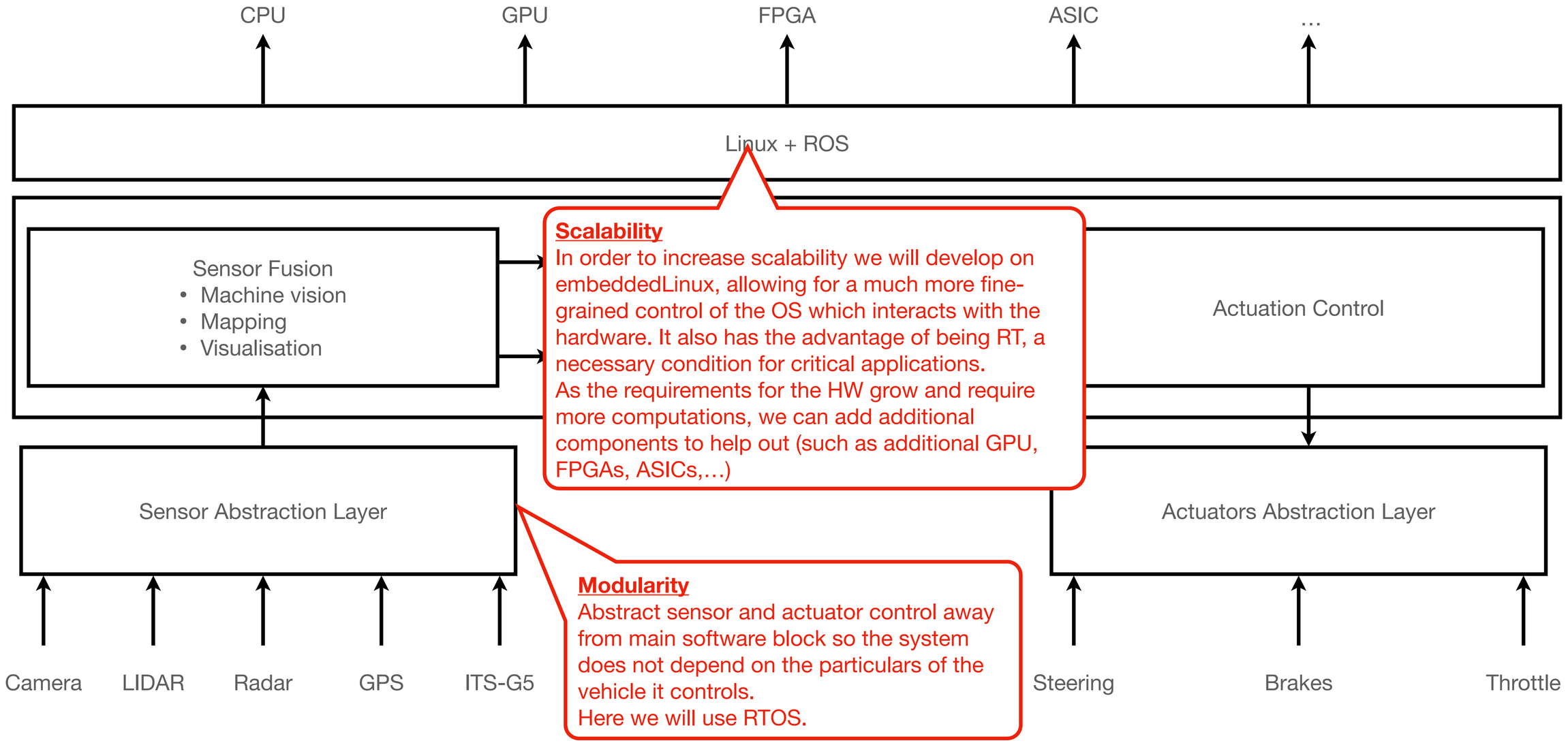
# Software Architecture



# Software Architecture



# Software Architecture

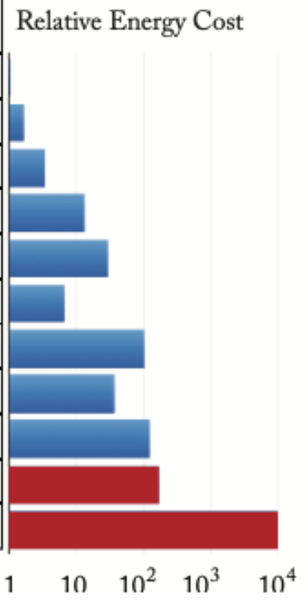


2. Where are the attention points/bottlenecks within the proposed architecture?

# Attention points/bottlenecks

- Safety
  - SW
    - Failure to detect object (correctly), faulty planning drive
    - Resistance to outside interference (hack)
    - Condition: HW is operating correctly
  - HW
    - Failure of sensor, computing unit, power,…
    - Redundancy: Overlapping sensor, multiple cores, power supply,…
- Throughput/Latency
  - Optimise software for minimal latency (NN!)
  - Parallelism?
    - Which tasks can take place simultaneously?
    - Dependencies?
  - Batching (increases latency)
  - Task precedence
  - Impact of environment?
    - City environment: lots of variables (pedestrians, road signs,…)
- Testing
  - Determine testing strategy for each unit
  - Usage of feedback loops?
- ROS
  - Mainly meant for r&d
  - “Security and scalability are not main concerns”

| Operation: | Energy (pJ) |
|---|---|
| 8b Add | 0.03 |
| 16b Add | 0.05 |
| 32b Add | 0.1 |
| 16b FP Add | 0.4 |
| 32b FP Add | 0.9 |
| 8b Mult | 0.2 |
| 32b Mult | 3.1 |
| 16b FP Mult | 1.1 |
| 32b FP Mult | 3.7 |
| 32b SRAM Read (8KB) | 5 |
| 32b DRAM Read | 640 |

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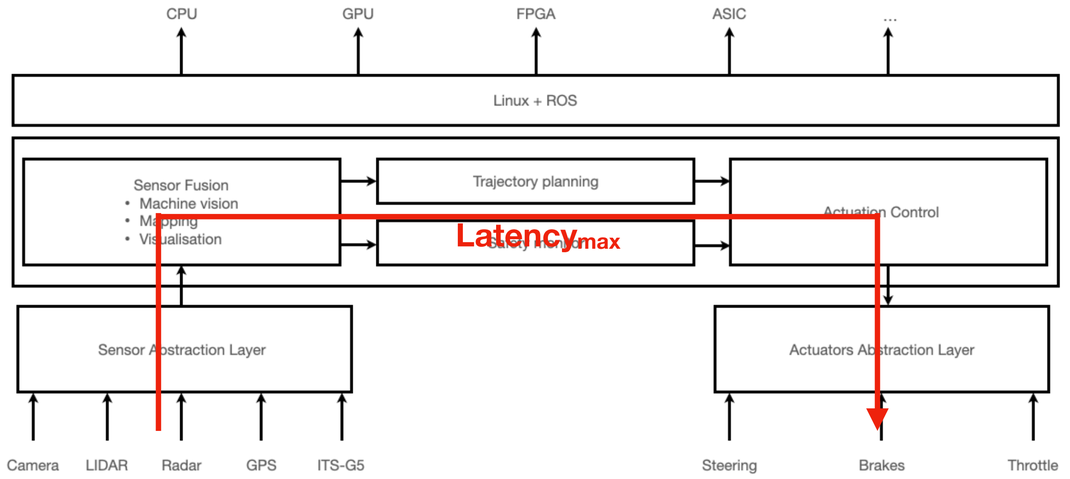
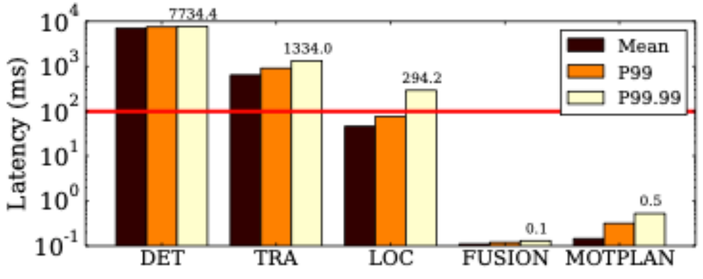
3. Propose derive hardware requirements, both performance as interface related, for the main blocks of perception, localization, decision making and actuation control?

# Hardware requirements

- Power & Energy (<xW)
  - DNN (perception)
    - # of NN layers
    - Bit precision
    - # of off-chip accesses (SRAM <-> DRAM accesses)
  - Cooling
- Latency & Throughput
  - 30 fps -> $Latency_{max}$ < 33ms
  - Min BUS speed:
    - 800 + 16 ~= 1 Gbit/s
  - HBM DRAM?
  - Optimize for:
    - Object Detection (YOLO, DNN-based)
    - Object Tracking (GOTURN, DNN-based)
    - Localization (ORB-SLAM, FE)
- Cost < x€
  - Development cost
    - Off-the-shelf hw <-> custom
  - Unit cost
    - Computing unit
    - Cooling
    - Redundancy
  - Production cost
- Flexibility
- Impulse/vibration resistance
- Thermal constraints

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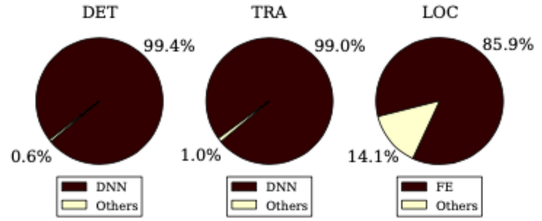
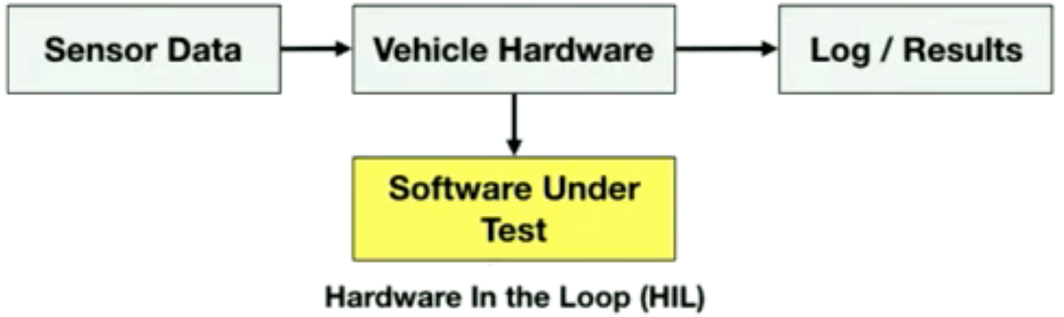


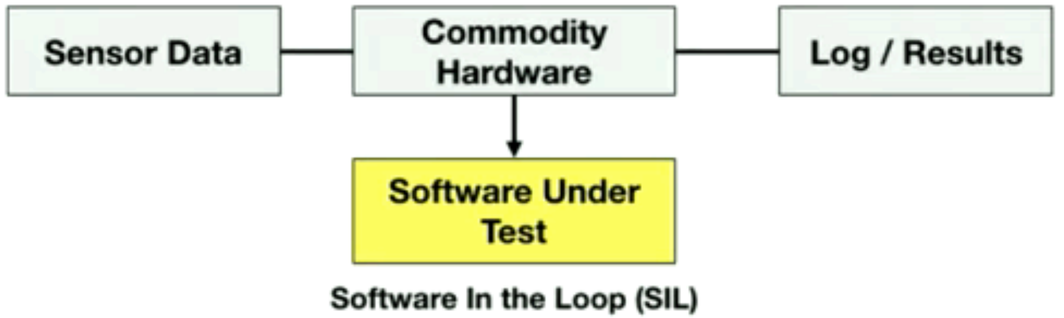

**Figure 7.** Cycle breakdown of the object detection (DET), object tracking (TRA) and localization (LOC) engines. The Deep Neural Networks (DNNs) portion in DET and TRA, and the Feature Extraction (FE) portion in LOC account for more than 94% of the execution in aggregation, which makes them ideal candidates for acceleration.

4. How can the proposed architecture be validated?

# Validation

- Simulation (SW)
  - Unit test for all sensors/actuators
  - Unit test for each software block of self-driving
  - Full testing of self-driving in simulation
    - Allows for intricate test adjustments
    - Account for difference real/simulated data
  - Testing using pre-recorded data (in simulation)
  - Simulation of city environment?
- Run H-I-L to verify hardware requirements
- Real Life Validation
  - Test track
  - City environment

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# Sources


- Autonomous driving systems hardware and software architecture exploration: optimising latency and cost under safety constraints
- A Standard Driven Software Architecture for Fully Autonomous Vehicles
- Efficient Processing of Deep Neural Networks: A Tutorial and Survey
- The Architectural Implications of Autonomous Driving: Constraints and Acceleration
- Efficient Processing of DNN
- Self-Driving Cars as Edge Computing Devices