POLITECNICO
DI TORINO

→ THE ESA EARTH OBSERVATION Φ-WEEK

EO Open Science and Future EO

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DEEP LEARNING FOR ENHANCED ON-BOARD AUTONOMY: EARTH OBSERVATION APPLICATIONS

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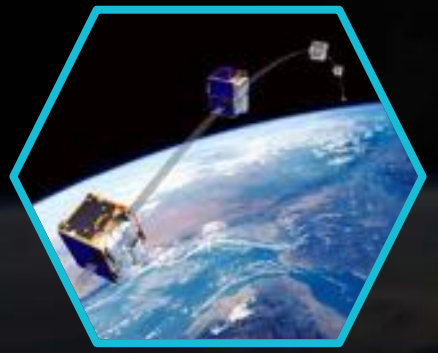
autonomY

spacecraft could take decisions in real time

instead of relying on time-consuming loops on the ground

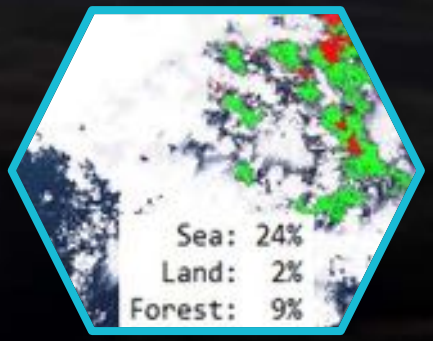


mega-constellations could self-manage

instead of planning manoeuvres on ground

downlinked data could be fully relevant

selecting and prioritizing data on-board



Spacecraft
Data acquisition
Basic healthkeeping
Basic processing

Ground Control Station
Data interface
Tracking

Mission Control Centre Infrastructure
Basic healthkeeping
Basic controlling

Scientific / Engineering Teams
Advanced healthkeeping
Data analysis
Payload target selection
Decision-making
Planning and scheduling
LEOP monitoring
Controlling

Spacecraft

- Data acquisition
- Advanced healtkeeping
- Advanced processing
- Decision-making
- Planning and scheduling

Ground Control Station

- Data interface
- Tracking

Mission Control Centre Infrastructure

- Basic healthkeeping
- Basic controlling
- Advanced healthkeeping
- Data analysis
- Payload target selection
- Decision-making
- Planning and scheduling
- LEOP monitoring

Scientific / Engineering Teams

- High-Level Monitoring

Future thanks to automation


E2
Current operations autonomy level
E4
Maximum theoretical autonomy level


Artificial intelligence

Telemetry &
Payload data

Artificial
Intelligence

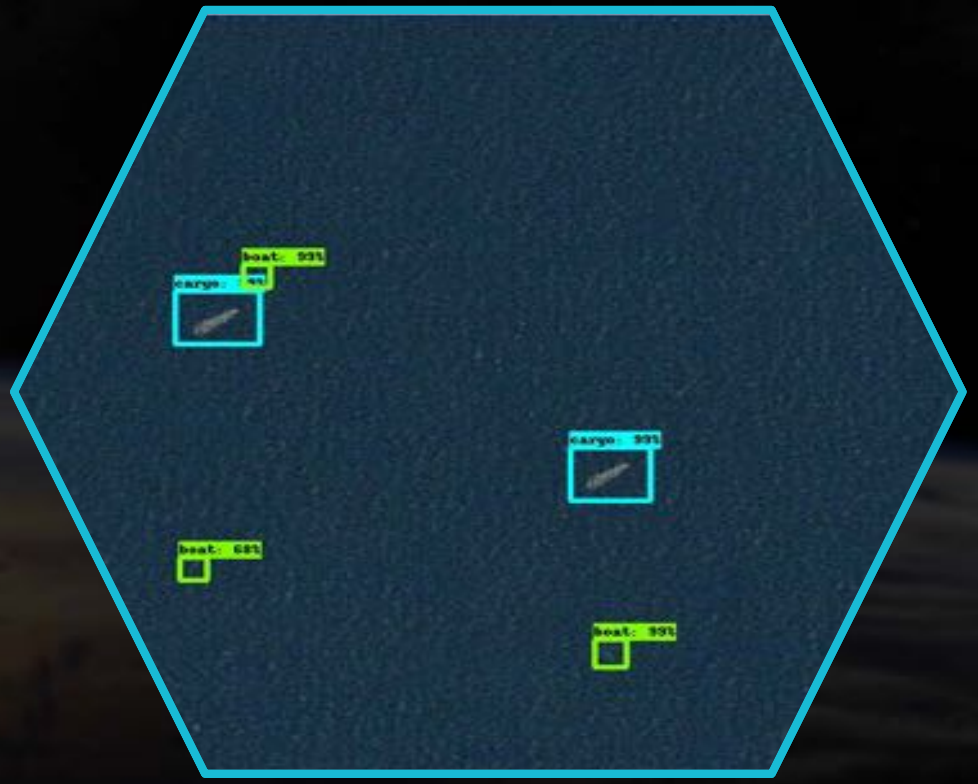
E4 Autonomy


spacecraft telemetry
payload data
Detection
Reasoning
Planning
spacecraft commands
decision-making support
Autonomy enabling technology

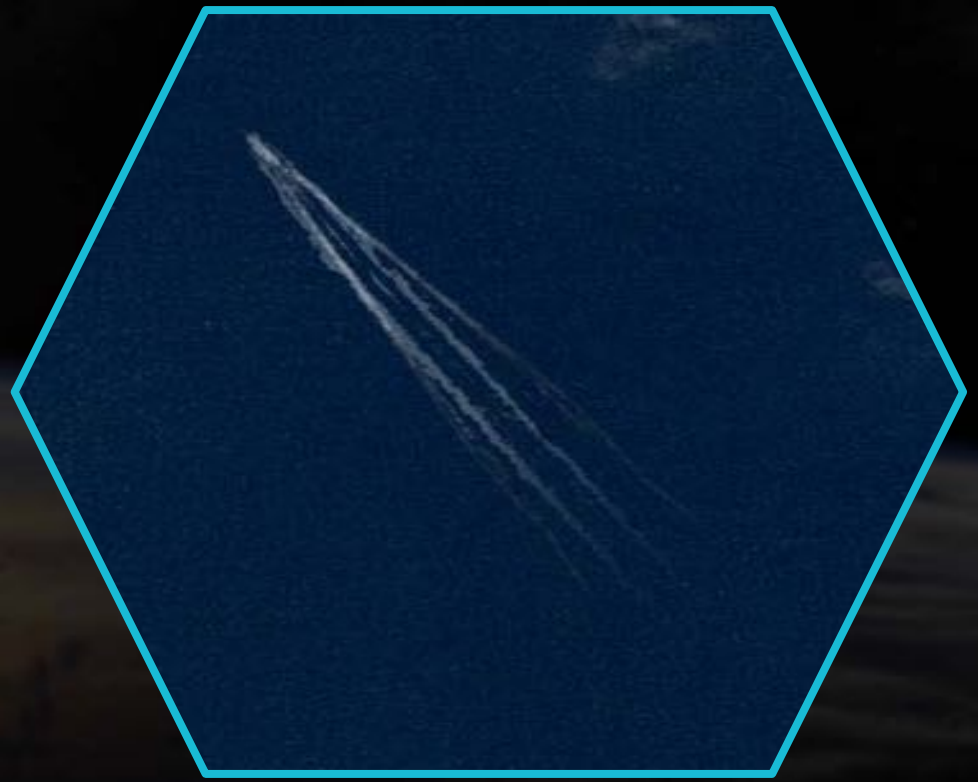
Deep Learning

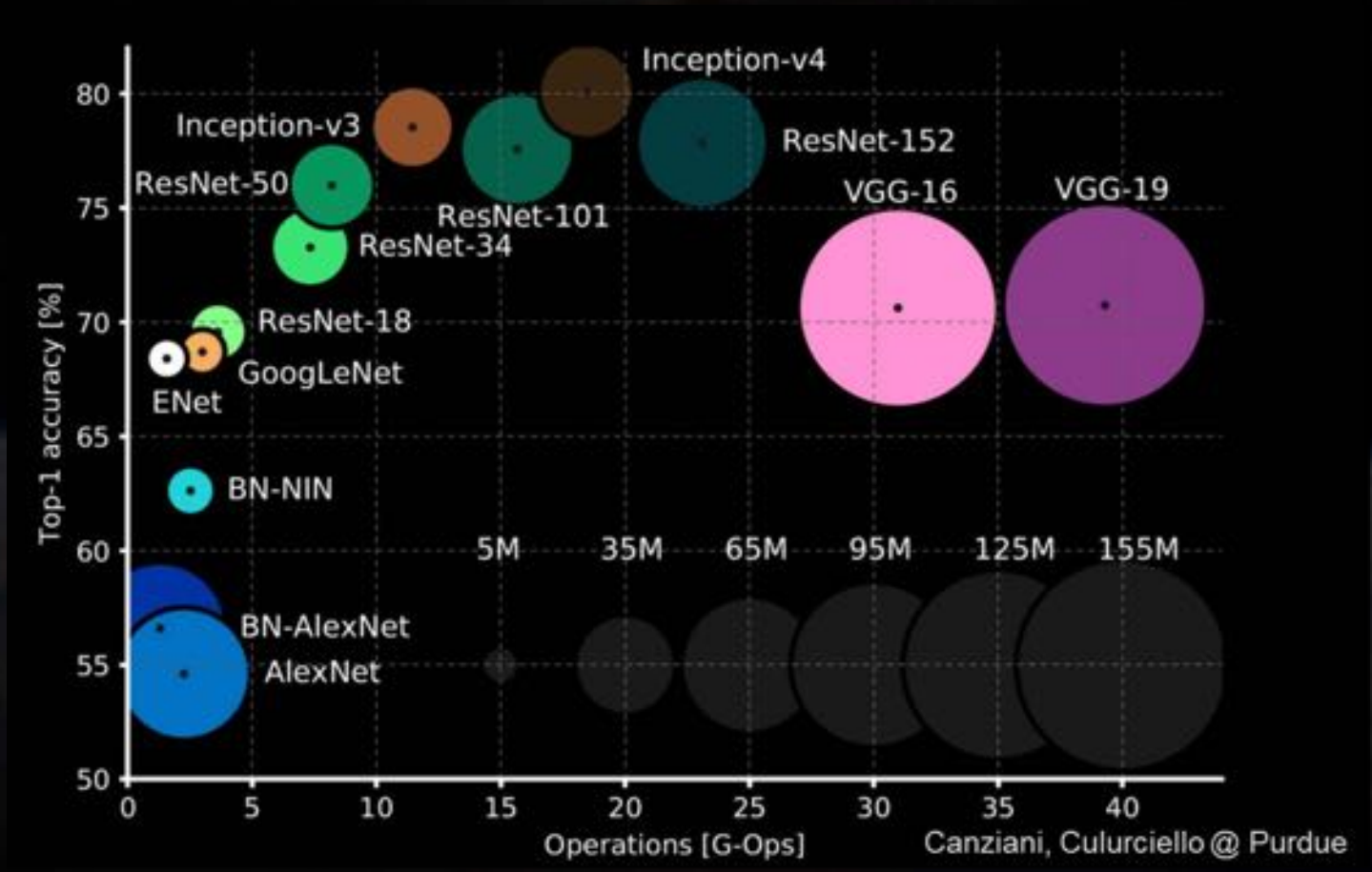
- Is the data being aquired useful for the mission?
  - Basic understanding of the data acquired during the mission
  - Various types of architectures can be used
- Classification is enough to increase autonomy
  - Perform data selection / prioritization before downlink
  - Trigger enhanced acquisition modes

- Why is the data useful? What is inside it?
  - Deeper understanding of the data acquired
  - CNN networks are predominant here
- Object Detection enables advanced autonomy features
  - Image crop only to relevant portions before downlink
  - Tracking of ground features



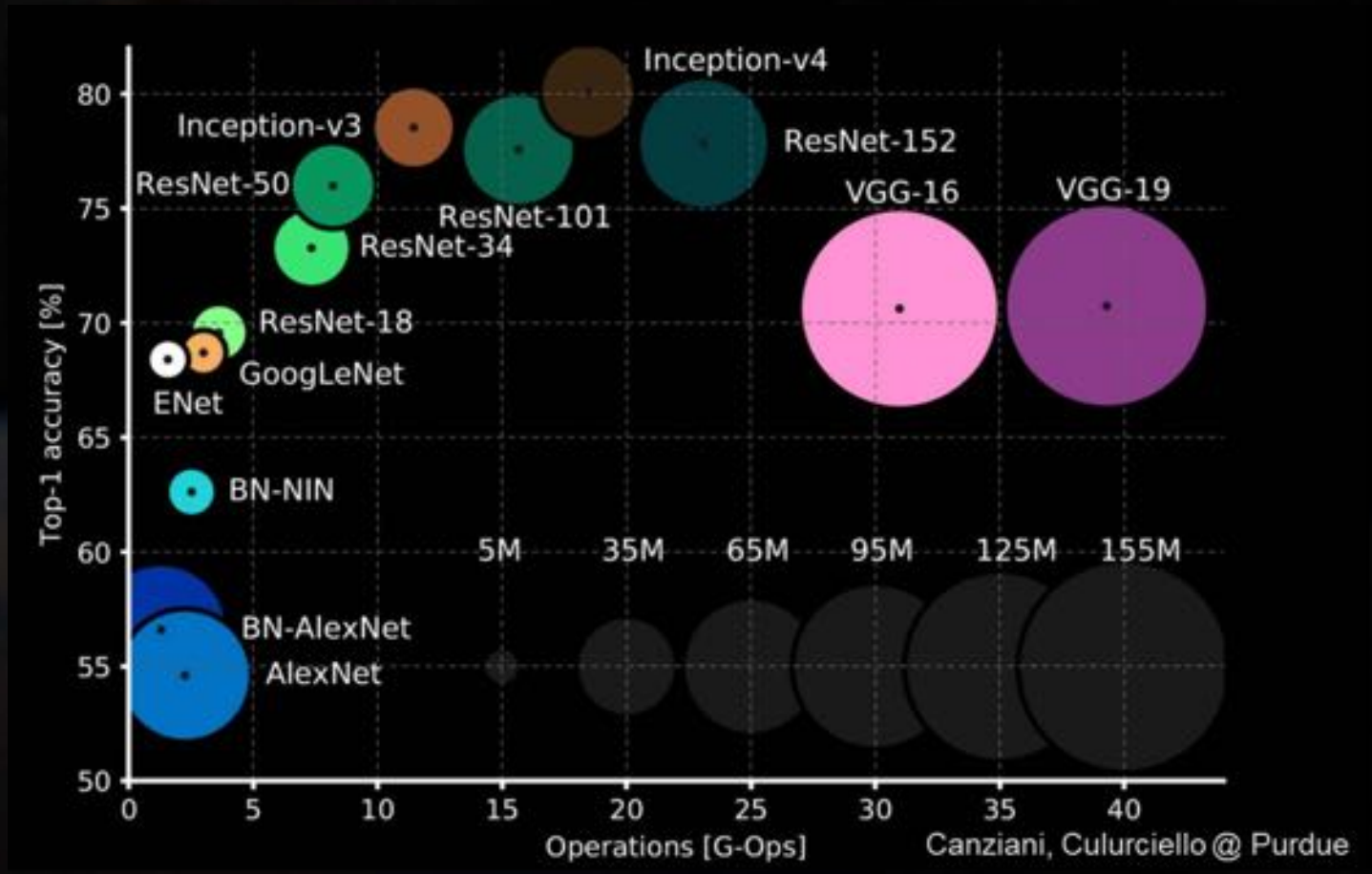
- Can we provide insights on the acquired data?
  - Extracting high level information from an image
  - Customization of the architecture increases in importance
- The satellites provide improved services
  - From wake features to speed information
  - Estimation of ship speed for security applications





Architecture design and selection

- What is the best architecture?
  - Problem-specific
  - Platform-specific
- What performances requirements?
  - State of the art networks that traditionally win image competitions are not compatible for on-board processors
  - Mandatory to move towards smaller architectures
- Execution times are promising
  - < 1s inference time for OD on a ARM9 processor for cloud detection



- Today technology is ready for enhanced autonomy
  - COTS processors are already meeting requirements for Deep Learning algorithms to be run on-board
- Enhanced autonomy will be a key driver in:
  - Reducing operations costs
  - Achieving more complex missions

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