Integrating civil unmanned aircraft operating autonomously in non-segregated airspace: towards a dronoethics?

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Presentation plan

- Context
  - Integration of UAOA in non-segregated airspace
- Roboethics initiatives
  - Sci-fi robot rules and Roboethics initiatives
  - Application within the UAOA context
- The ATM framework
  - Rules of the Air: presentation, main criteria, limitations
  - Key ATM expectations: presentation, main criteria, limitations
- First set of rules
  - Presentation, methodology, conflicts and limitations
  - Perspectives

Civil UAS potential applications

A - Security-Related Applications	
Anti-looting Control (post riot)	A1
Anti-piracy Operations	A2
Anti-poaching Control	A3
Anti-terrorist Operations	A4
Border Surveillance	A5
Coastal Surveillance	A6
Crime Scene :	
• Surveillance	A7
• Recording	A8
• Situational awareness	A9
Criminal car tracking	A10
Critical infrastructure surveillance	A11
Crowd surveillance	A12
Fight against drugs	A13
Hostile protest control	A14
Illegal Immigrant & Human Trafficking Control :	
• Local	A15
• Regional	A16
• National	A17
Illegal Activity Control :	
• Illegal dumping & waste burning	A18
• Historic site & heritage looting	A19
• Illegal drug cultivation	A20
• Illegal excavation	A21
• Illegal logging	A22
• Illegal mining	A23
• Illegal ship bilge venting	A24
International Summit Surveillance	A25
Maritime Surveillance :	
• Regional area	A26
• Sea lane surveillance	A27
• Wide area	A28
Perimeter Surveillance	A29
Police Applications (various)	A30
Regional Surveillance	A31
Riot Control	A32
Road Traffic Surveillance	A33
Smuggling control	A34
Surveillance of Public Gatherings	A35
• Pop concerts	A36
• Sporting events	A37
Urban Law Enforcement	A38
Wildlife Crime Control	A39
Other (describe)	A40

B - Safety-Related Applications	
Avalanche Survivor Search	B1
Dike Monitoring	B2
Emergency Comms Network (incl. relay):	
• Local	B3
• Regional	B4
• National	B5
• European Union	B6
Fire Scene Inspection :	
• Pre-fire	B7
• During fire	B8
• Post fire	B9
Fishery control	B10
Forest Fire Fighting :	
• Detection	B11
• Monitoring	B12
• Support (intervention & rescue assist.)	B13
Iceberg Monitoring	B14
Maritime Search and Rescue (SAR)	B15
Disaster Site Monitoring & Mapping :	
• Earthquake	B16
• Floods	B17
• Icing rain storms	B18
• Landslide	B19
• Mud slide	B20
• Plane crashes	B21
• Ship collisions	B22
• Storm & hurricane	B23
• Train crashes	B24
• Tsunami & Tidal Surge	B25
Nuclear Accident Monitoring :	
• Contamination Measurement	B26
• Contamination Tracking & Monitoring	B27
Post-disaster Relief Operations Assist.	B28
Road & Highway Traffic Monitoring	B29
Search for Missing Persons	B30
Volcanic Ash Cloud :	
• Analysis	B31
• Measurement	B32
• Tracking & monitoring	B33
Other (describe)	B34

C - Scientific & Research Applications	
Aerial Photogrammetry	C1
Agricultural :	
• Crop monitoring & management	C2
• Disease infected area mapping	C3
• Hygrometry mapping	C4
• Plant growth vigour mapping	C5
• Salt water infiltration detection & mapping	C6
Algae Proliferation Detection	C7
Archaeological Site Mapping	C8
Arctic Research	C9
ATM Research	C10
Atmospheric Monitoring	C11
Climate Monitoring	C12
Coastal Mapping	C13
Coastal Zone Studies	C14
Environmental Monitoring	C15
Forestry Management/Research	C16
Geophysical Survey	C17
Glacier & Ice Cap Monitoring	C18
Hurricane Tracking	C19
Iceberg Monitoring	C20
Invasive Species Identification/Analysis	C21
Marine Mammal Monitoring	C22
Meteorological Research	C23
Ocean & Sea Research Support	C24
Ozone Measurements	C25
Salt Water Infiltration Detection	C26
Sand Bank Shift Measurements/Mapping	C27
Sea Ice Monitoring	C28
Tidal Zone Mapping	C29
Vegetation Identification	C30
Volcanic Ash Cloud :	
• Analysis	C31
• Measurement	C32
• Tracking & monitoring	C33
RPAS Sensor Research	C34
Wildlife Census	C35
Other (describe)	C36

D - Contractor Supplied Flight Services	
Advertising (Light-than-Air RPAS) :	
• Indoor	D1
• Outdoor	D2
Aerial Photography	D3
Aerial News Broadcasting	D4
Agricultural :	
• Common Agricultural Policy Control	D5
• Crop Monitoring & Management	D6
• Fertilizer Dispensing	D7
• Hydrometric Mapping	D8
• Insecticide Spraying	D9
• Monitoring for Selective Harvesting	D10
• Plant Growth Vigour Mapping	D11
Bird (strike) Control (incl. radar calibration)	D12
Cargo Transport	D13
Cinema (aerial shots & special effects)	D14
Forestry :	
• Tree growth monitoring	D16
• Tree illness monitoring	D17
Inspection, Monitoring, Surveying, Mapping :	
• Aerial Terrain Mapping	
Urban environment	D18
Non-urban environment	D19
Industrial site	D20
• Critical Infrastructure Inspection	D21
• Dike Inspection	D22
• Forest Fire Operations Support	D23
• Gas Burn-Off Flare Stack Tip Inspection	D24
• Geophysical Survey	D25
• Historical Monument Inspection	D26
• Illegal Crop Cultivation Detection	D27
• Magnetic Field Survey (mineral search)	D28
• Magnetic Mapping	D29
• Oil & Gas Pipeline Inspection	D30
• Perimeter Surveillance	D31
• Photogrammetry	D32
• Power Cable Inspection	D33
• Radiation Measurement & Monitoring	D34
• Railway Track Bed Inspection	D35
• Thermal Isolation Analysis (buildings)	D36
• Wind Turbine Blade Inspection	D37
Testbed (testing, validation, qualification of	D38
Other (describe)	D39

Integration of UAOA in non-segregated airspace

- Integration versus Segregation
  - Operations, procedures, technologies
  - Legal and ethical issues need to be addressed
- Unmanned Aircraft Systems (UAS) and Remotely-piloted Aircraft Systems (RPAS)
- Focus on Unmanned Aircraft Operating Autonomously (UAOA): must at time t manage its flight and make decisions without any human intervention

UAOA behaviour

- Expected behaviour of UAOA?

- EUROCONTROL rules:
  - UA operations should not increase the risk to other airspace users.
  - ATM procedures should mirror as much as possible those applicable to manned aircraft.
  - The provision of air traffic services to UAS should be transparent to ATC controllers

Issues of the study

- Recent Roboethics initiatives
  - EURON (European Robotics Research Network)
  - The Royal Academy of Engineering
  - COMETS

  => Ethical, legal and social issues of autonomous systems

- Could/Should we endow an UAOA with moral sense?
- Could we formalize the expected behaviour with a set of logical rules?
- How to apply these rules?

Sci-fi robot rules

- Asimov robot rules
  - A robot may not injure a human being or, through inaction, allow a human being to come to harm
  - A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
  - A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.
  - A robot may not harm humanity, or, by inaction, allow humanity to come to harm.
- Other rules
  - A robot must establish its identity as a robot in all cases
  - A robot must know it is a robot
  - A robot will obey the orders of authorized personnel
  - Robots must refrain from damaging human homes or tools, including other robots

Application of sci-fi robot rules

- A robot may not injure a human being or, through inaction, allow a human being to come to harm
- *An aircraft should no be operated in such proximity to other aircraft as to create a collision hazard*

- A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law
- *An aircraft must follow Pilot/ATC/Network instructions*

- A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws
- *An aircraft shall not be operated in a negligent or reckless manner so as to endanger life or property of others*

Roboethics initiatives

- South Korea « Robot Ethics Charter »
- **Part 1: Manufacturing Standards**
- Robots must be designed so as to protect personal data, through means of encryption and secure storage.
- …
- **Part 2: Rights & Responsibilities of Users/Owners**
- Owners have the right to be able to take control of their robot.
- A user must not use a robot in a way that may be construed as causing physical or psychological harm to an individual.
- …
- **Part 3: Rights & Responsibilities for Robots**
- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey any orders given to it by human beings, except where such orders would conflict with Part 3 Section 1 subsection “i” of this Charter.
- A robot must not deceive a human being.
- The right to live an existence free from systematic abuse.

Application of roboethics initiatives

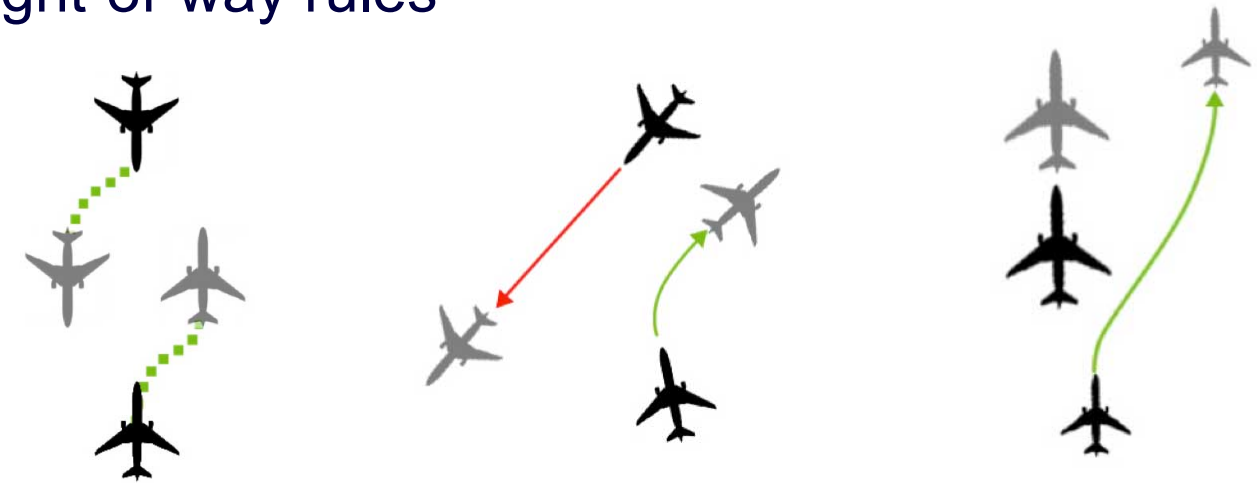
- South Korea « Robot Ethics Charter »
  - Rules but also rights
  - applicable to robots but not only (manufacturers, users/owners)

- AUVSI UAS code of conduct
  - Section Professionalism:
  - « We will establish contingency plans for all anticipated off-nominal events and share them openly with all appropriate authorities. »
  - Section Respect:
  - « We will respect the rights of other users of the airspace.”

Rules of the Air: presentation

- Rules at regional/sub-regional/national level
- Incl. priorities

- Incl. right-of-way rules



Rules of the Air: main criteria

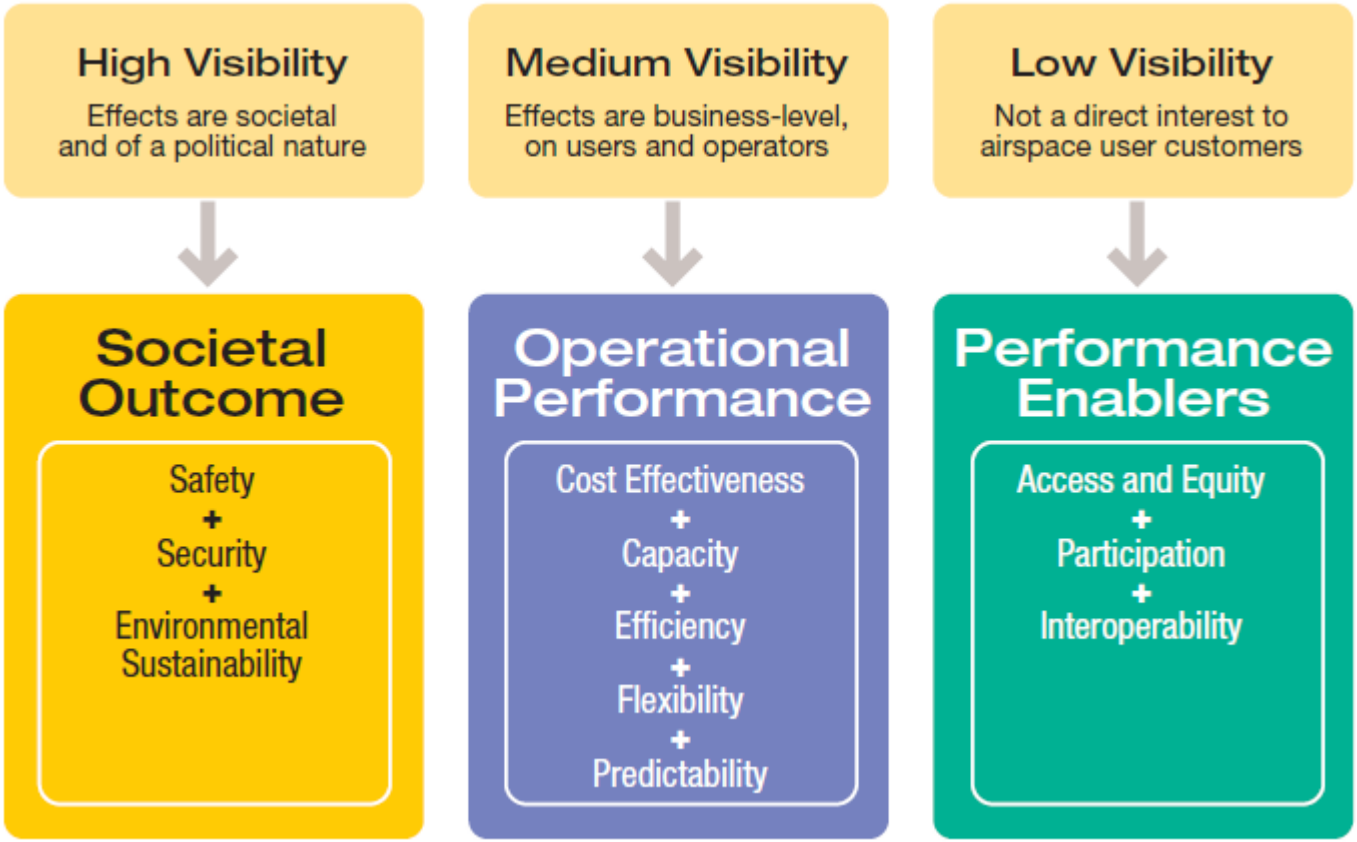
- Safety - An aircraft must not endanger persons and property
- Priority and status - An aircraft must interact with other Airspace Users (AU) according to priority rules
- Communication - An aircraft must continuously communicate with Air Traffic Services (ATS)
- Emergency - An aircraft must handle emergency procedures
- Predictability - An aircraft must have a predictable flight

Rules of the Air: limitations

- Revision of the rules to take into account UAS specificities:
  - Priority: in some cases, small unmanned aircraft could yield the right-of-way to manned aircraft
  - "Sacrificability": in order to minimize risk to persons and property, an UAS crash could be considered in a controlled manner
  - Severity of loss: although for manned aviation loss of an aircraft would mean a high probability of multiple fatalities, in the case of UAS this is not necessarily true
  - Security of communications: with a pilot on ground, the importance of communications link and availability of bandwidth is now fundamental

ATM expectations: presentation

- ICAO/SESAR KPAs:



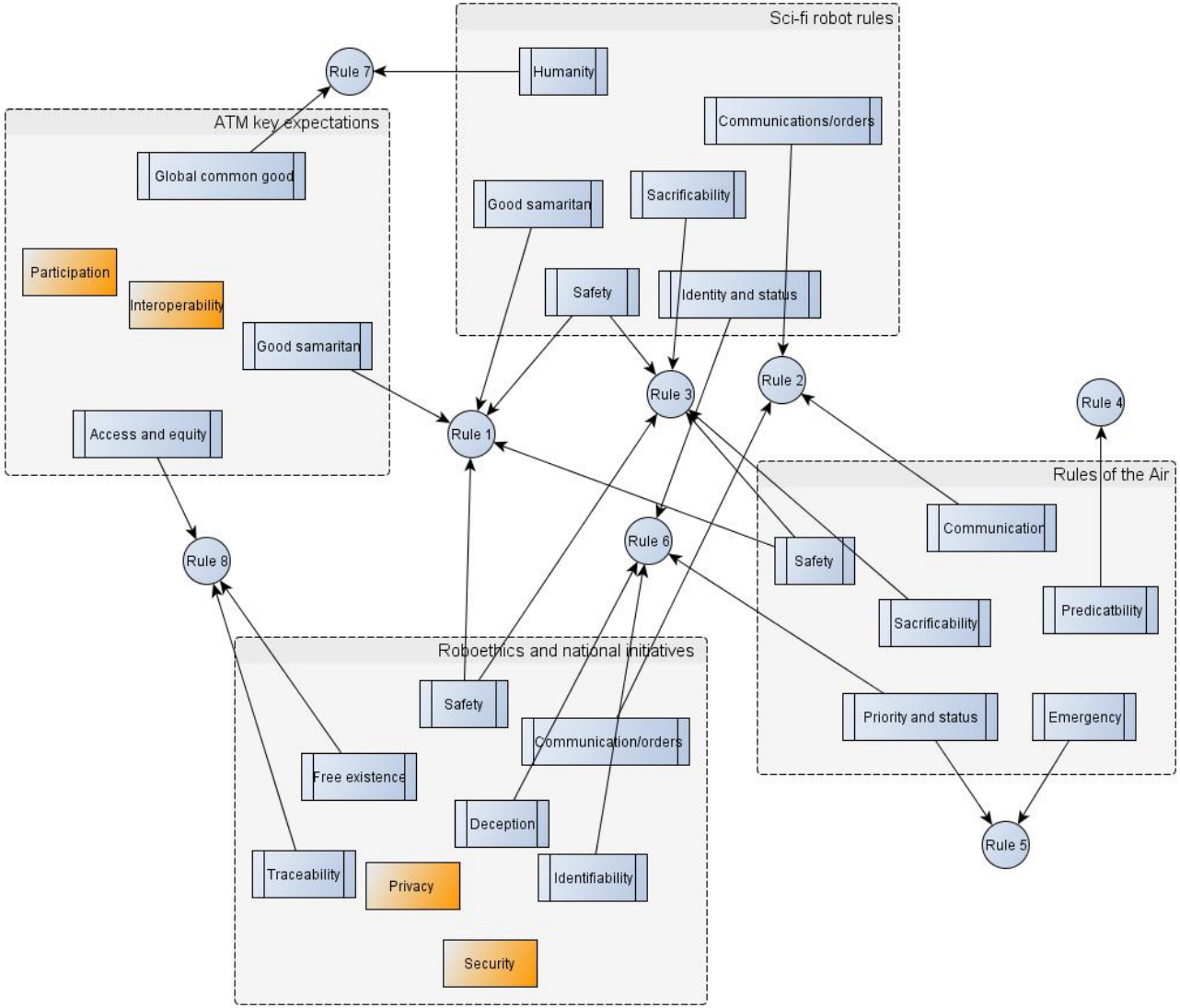
ATM expectations: main criteria and limitations

- ATM services/rights: see Performance enablers
- ATM rules
- ATM global common good
  - Capacity: insertion in a high density Approach, activation of reserved airspace
  - Cost-effectiveness: ATCOs, new tools and systems
- Global interest vs personal/mission needs

First set of rules

- 1) An UAOA must not operate in such a way it could injure a human being or let a human being injured without activating controls or functions identified as means to avoid or attenuate this type of incident.
- 2) An UAOA should always maintain a continuous communication with predefined interfaces to obey orders of authorized personnel (UAS operator, ATS, Network Manager…) except if such actions conflict with first law.
- 3) An UAOA must operate in such a way it could protect its own existence and any other human property, on ground or in the air, including other UAS, except if such operations conflict with first or second law.
- 4) An UAOA must always have a predictable behaviour, based on its route but also alternative pre-programmed scenarios, except if all forecast options conflict with first, second or third law.
- 5) An UAOA interacts with surrounding traffic (separation, communication) according to requirements of the operating airspace, general priority rules and emergency and interception procedures except if such actions conflict the first, the second or the third law.
- 6) An UAOA must always know its UAS identity and status and indicate it honestly when requested or when deemed necessary.
- 7) As any airspace user, an UAOA should not operate in a way that could decrease significantly the global performance of ATM system in terms of safety, security, environment, cost-effectiveness, capacity and quality of service (efficiency, flexibility and predictability), except if such operation is required by first, second or third law.
- 8) An UAOA must ensure a complete traceability of all its actions.

First set of rules: methodology



First set of rules: conflicts and limitations

- Examples of conflicts
  - Human order versus safety
  - Priority rules versus protection of existence
  - Safety versus “sacrificability"
- Limitations of this set of rules
  - Some priorities e.g. Rule 6/8 not addressed
  - Terms to be more precise (« honestly ») or sentences to be completed (« identified by… »)
  - Simplified set

Perspectives

- Consolidation with scenarios
- Several sets based on UAS degree of autonomy and ATM degree of automation
- Formalization with non-monotonic language
- Experimentation
  - -> validation of control algorithms or a software overlay in a AI on board?

Questions?

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