DEFENCE R&D DÉFENSE

Unmanned Systems Working Group

Considerations on Autonomy

F Wong, C A Rabbath

Defence Research and Development Canada
Recherche et développement pour la défense Canada

Canada

CF Concept Development Observations

- Future security environment will consist of unrest due to disillusioned unemployed youth, disagreements generated by the race to access natural resources, and distress due to climatic changes in different regions in the world.
- Network essential to future operations.
- Adaptive force structure that allows dispersion and amassing of force elements according to mission.
- Robots will be employed in a layered approach.
- Need to determine how robots and humans can work together to make decisions and execute missions.
- Legal implications of including autonomy in the decision loop needs to be clarified.

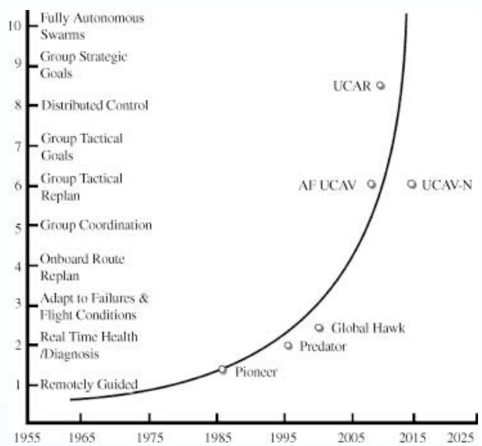
CF Requirements/Operations Observations

- Robots must address high impact, common tasks at affordable cost.
- Integration of UAVs into non-segregated airspace.
- All weather operations.
- Tighten sensor to shooter loop by arming UAVs with precision guided weapons.
- One operator-multiple platform operation.
- Minimization of operator workload and dependency on operations training.
- Automated data analysis and operator cueing.

Definitions of Autonomy

DoD Unmanned Aerial Vehicles Roadmap 2002

www.dtic.mil/cgi-bin/GeTRDoc?AD=ADA515926



Level	Level Descriptor	Perception/Situational Awareness	Analysis/Decision Making	Communication/Cooperation
10	Human-Like			
9	Multi-Vehicle Tactical Performance Optimization	Detection & tracking of other air vehicles within airspace	Full decision making capability on-board Dynamically optimize multi-ship group for tactical situation	Distributed cooperation with other air vehicles On-board deconfliction and collision avoidance Fully independent of supervision/control if desired; No centralized control within multi-UAV group
8	Multi-Vehicle Mission Performance Optimization	Detection & tracking of other air vehicles within local airspace OK to operate in controlled airspace w/o external control	Continuous mission/trajectory evaluation & replan - optimize for current mission situation Avoid collisions and replan/optimize trajectory to meet goals, etc	External supervision - abort/recall or new overall goal On-board deconfliction & collision avoidance Distributed cooperation with other A/V's
7	Real-Time Multi-Vehicle Cooperation	Detection of other A/V's in local airspace Multi-threat detection/analysis on-board	Continuous flight path evaluation & replan Compensate for anticipated system malfunctions, weather, etc - optimize trajectory to meet goals, manage resources, avoid threats, etc	On-board collision avoidance Uses off-board data sources for deconfliction & tracking Hierarchical cooperation with other A/V's
6	Real-Time Multi-Vehicle Coordination	Detection of other A/V's in local airspace Single threat detection/analysis on-board	Event-driven on-board, RT flight path replan - goal driven & avoid threats RT Health Diagnosis; Ability to compensate for most failures and flight conditions - inner loop changes reflected in outer loop performance	On-board collision avoidance Uses off-board data sources for deconfliction & tracking Assumed acceptance of replan; External supervision - rejection of plan is exception Possible close air space separation (1-100 yds)
5	Fault/Event Adaptive Vehicle	Automated Aerial Refueling & Formation sensing Situational awareness supplemented by off-board data (threats, other A/Vs, etc)	Event-driven on-board, RT traj replan to new destination RT Health Diagnosis; Ability to compensate for most failures and flight conditions; Ability to predict onset of failures (e.g. Prognostic Health Mgmt) On-board assessment of status vs trajectory	On-board derived vehicle trajectory "corridors" Uses off-board data sources for deconfliction & tracking External supervision - accept/reject of replan Possible close air space separation (1-100 yds) for AAR, formation in non-threat conditions
4	Robust Response to Anticipated Faults/Events	Threat sensing on-board	RT Health Diagnosis (Can I continue with these problems?); Ability to compensate for most failures and flight conditions (e.g. Adaptive inner loop control); Automatic trajectory execution; On-board assessment of status vs mission completion	Secure, within LOS electronic tether to nearby friendlies Offboard derived vehicle "corridors"; Medium vehicle airspace separation (100's of yds) Threat analysis off-board
3	Limited Response to Real Time Faults/Events		RT Health Diag (What is the extent of the problems?) Ability to compensate for limited failures (e.g. Reconfigurable Control) Automatic trajectory execution	Health Status monitored by external supervision Off-board replan; Waypoint plan upload Wide airspace separation requirements (miles)
2	Pre-loaded Alternative Plans		RT Health diagnosis (Do I have problems?) Automatic trajectory execution (via waypoints) Preloaded alternative plans (e.g. abort)	External commands - alternative plans, approvals, aborts Reports status on request or on schedule Wide airspace separation requirements (miles)
1	Execute Preplanned Mission	Situational awareness via Remote Operator Flight Control and Navigation Sensing	Robotic/Preprogrammed Pre/Post Flight BIT	External control via low level commands Reports status on request Wide airspace separation requirements (miles) No on-board knowledge of other air vehicles - all actions are preplanned
0	Remotely Piloted Vehicle	Flight Control (attitude, rates) sensing Nose camera Situational awareness via Remote Pilot	N/A	Remotely Piloted Vehicle status data via telemetry

Definitions of Autonomy

Human-centred computing perspective

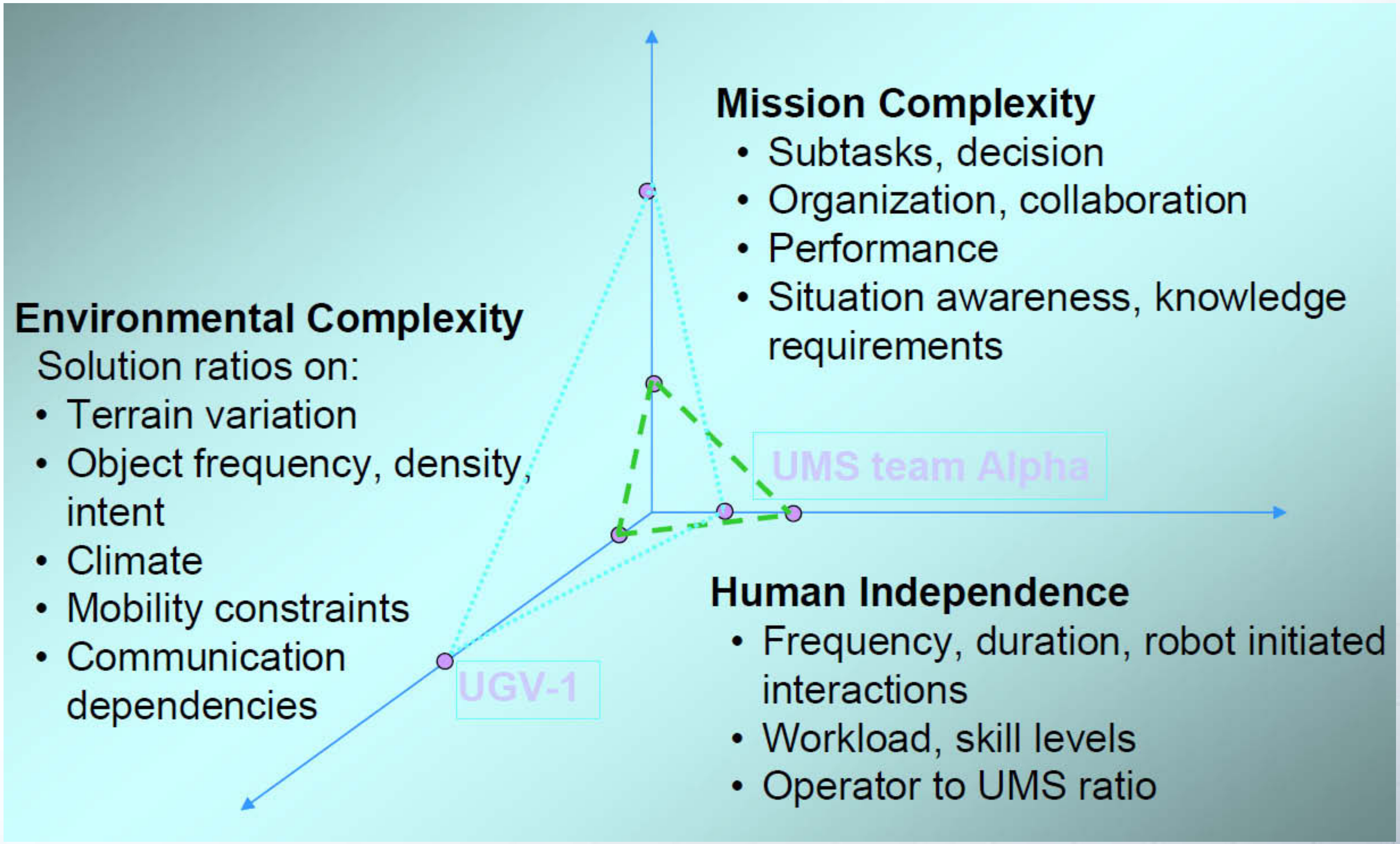
www.computer.org/intelligent

Level	Description
High	10. The computer decides everything, acts autonomously, ignoring the human.
	9. The computer informs the human only if it, the computer, decides to.
	8. The computer informs the human only if asked, or
	7. The computer executes automatically, then necessarily informs the human, and
	6. The computer allows the human a restricted time to veto before automatic execution, or
	5. The computer executes that suggestion if the human approves, or
	4. The computer suggests one alternative
	3. The computer narrows the selection down to a few, or
	2. The computer offers a complete set of decision/action alternatives, or
Low	1. The computer offers no assistance; the human must take all decisions and actions.

Definitions of Autonomy

Autonomy Levels for Unmanned Systems (ALFUS)

http://www.nist.gov/el/isd/ks/autonomy_levels.cfm



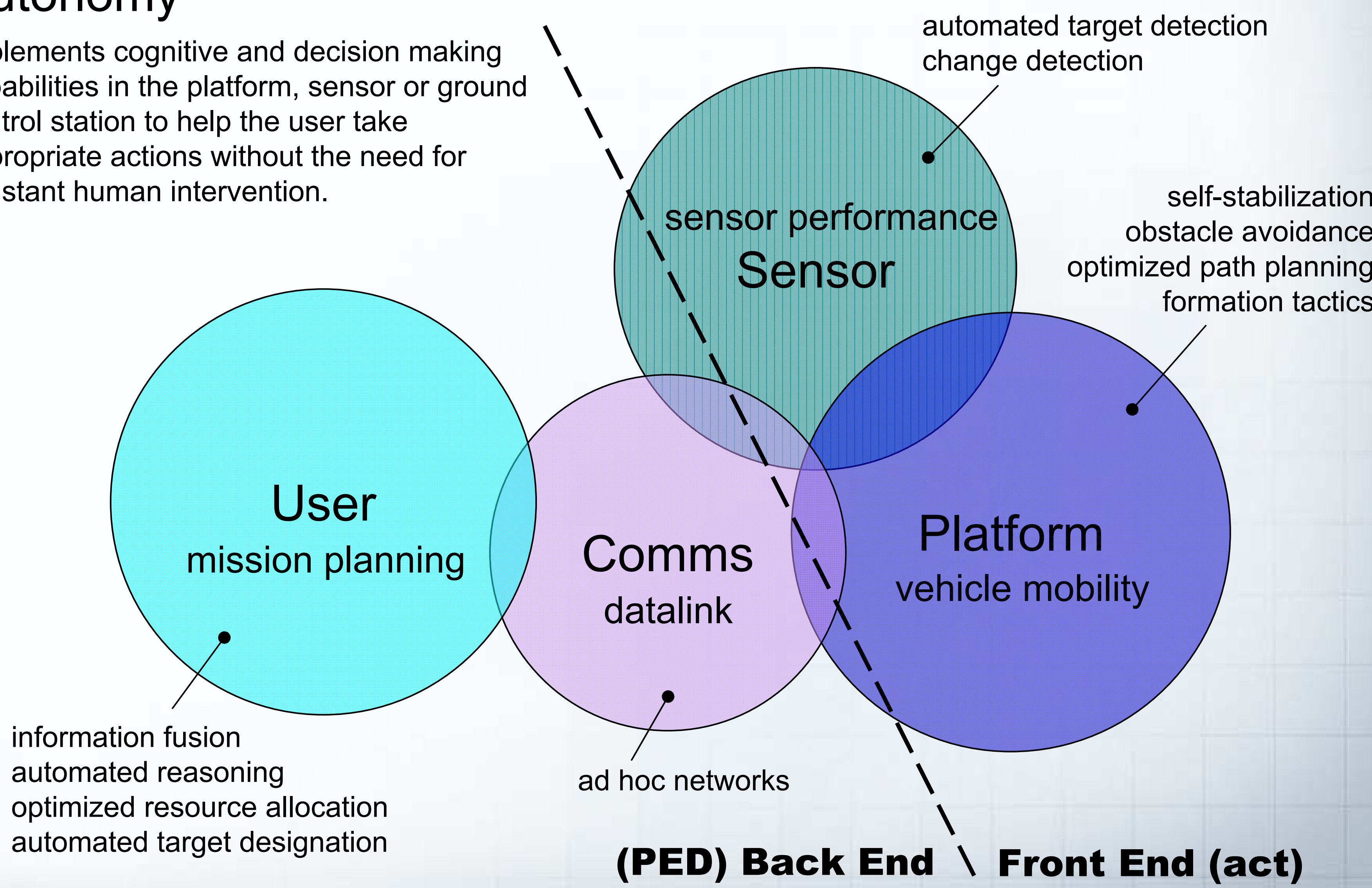
DRDC US WG Definition of Autonomy

- Near term
  - An autonomous system is a human-centric system that employs automated aids to reduce cognitive and physical burden.
- Far term
  - An autonomous system is a intelligence-centric system that is able to learn, understand, and act according to the intent of the commander.

System Technology Domains

Autonomy

Implements cognitive and decision making capabilities in the platform, sensor or ground control station to help the user take appropriate actions without the need for constant human intervention.



One Point of View on Evolution of Autonomous Capabilities for Naval ASMD

DEFENCE R&D DÉFENSE

	MOBILITY / PLATFORM	SENSOR / PAYLOAD	DATALINK	COMMAND & CONTROL
HORIZON 1	Organic to ship •1 platform •Fixed Wing (10kg payload) •Rotary Wing (150 kg payload) •Aerostat (50 kg payload) •Heavy fuel engine •COTS autopilot •Way-point following	DETECTION •Low Power radar (COTS) PROTECTION • NAVIGATION •GPS	LOW BANDWIDTH •SatCom (COTS) HIGH BANDWIDTH •LOS/RF	HUMAN-ONLY DECISION Mission planning Target classification Weapon release MACHINE DECISION Target detection
HORIZON 2	Same as Horizon 1 + •1 to 2 platforms •Cooperative behavior •ADS-B based obstacle avoidance •Increased payload •Increased endurance	Same as Horizon 1 + DETECTION •EO/IR suite for small UAV •Extended range radar PROTECTION • NAVIGATION •ADS-B	Same as Horizon 1 + •Affordable military comms package (LINK16)	Same as Horizon 1 + HUMAN-ONLY DECISION MACHINE DECISION •Mission planning optimization •Assisted mission planning •Automated target recognition
HORIZON 3	Same as Horizon 2 + •1 to n platforms •Flocking behavior •Sense & Avoid •Increased payload •Increased endurance	Same as Horizon 2 + DETECTION •Synthetic aperture radar on multiple UAVs PROTECTION •Hardkill effector •Software defined RF-Jamming suite NAVIGATION •Visual (EO/IR) integration	Same as Horizon 2 + •Software detected jamming resistance •SatCom (MOTS)	Same as Horizon 2 + ONLY HUMAN DECISION Assisted Hardkill engagement 1 x Operator for Multiple USVs MACHINE DECISION •Automated target classification •Assisted target/weapon matching for onboard hardkill effector