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Introduction: Achieving Intelligence in Aerospace Systems

IT is hard to argue that achieving intelligence (in any artificial system) has been elusive, at least what would be considered a high degree of intelligence (DOI). Albus has suggested that intelligence is ". . . the ability of a system to act appropriately in an uncertain environment, where appropriate action is that which increases the probability of success, and success is the achievement of behavioral sub goals that support the system's ultimate goal." Measurable engineering parameters that enable behavior comparable to that demonstrated by living creatures may include the ability of intelligent systems to:[2]

- Sense the environment and the internal state of the machine.
- Perceive and recognize objects, events, and situations.
- Remember, understand, and reason about what is perceived.
- Attend to what is important and ignore what is irrelevant.
- Predict what will probably happen in the future under a variety of assumptions.
- Evaluate what is perceived and predicted.
- Make decisions, plan, and act so as to achieve goals.
- Learn from experience and from instructions.

Intelligence can be defined functionally by how well a system performs functions generally associated with intelligence (listed above). A system will have a number of missions to keep in "mind." There is usually a main mission, such as reaching the Space Station for the Shuttle, but other secondary missions might include a limited use of fuel, quick turnaround after returning to Earth, quick assessment of pre and post flight conditions, extension of the life of its propulsion system, etc. Analogous missions apply to aircraft.

If one considers the systems to encompass all people and other resources involved in their operation, then we do have systems with a high degree of intelligence (DOI). For instance, the Space Shuttle is operated by thousands of people from the ground. Aircraft also require large teams of people if one considers air traffic control, inspections, diagnostics, and maintenance as secondary missions to be achieved. However, this scenario has two major problems. It is very costly (labor), and the safety goals today are far from satisfactory. In the case of longer missions to Mars, or unmanned missions (space and military), systems embedded with a high DOI are inherently required by the nature of the missions. Therefore, to develop, operate, maintain, and retire systems in what NASA calls a "sustainable" manner, and to satisfy inherently unmanned missions; a great deal of the intelligence that currently resides on ground (people) must be embedded on-board the systems. The objective is to embed enough data, information, and knowledge (DIaK) so that the system and its on-board operator(s) embody a high DOI.

Embedding the functions that denote intelligence (listed after the first paragraph) in an aircraft means that the system must posses, an embedded Intelligence Engine (IE) that understands the system (models—analytical, statistical, numerical, fuzzy, etc.), failure models, strategies to deal with known and unknown anomalies, strategies to diagnose causes of anomalies and to predict future anomalies, strategies to plan operations with current conditions and predicted future conditions; all of this while keeping in "mind" its missions. Hence, embedding an IE is a highly complex task that can only be achieved by integrating various technologies, architectures, taxonomies, ontologies, standards, and protocols.

An essential concept to achieve intelligence is that intelligence is not embedded at once at design, but it must increase from a minimum to higher and higher degrees (by manual or automatic learning). Therefore, the infrastructure to embed intelligence must be scalable, expandable, modular, and easy to modify/maintain. Key elements of the infrastructure are the architecture, taxonomy, ontology, and standards. To draw an analogy, these are the very same elements that have laid the foundation for the World Wide Web (WWW). The WWW model has worked well as an infrastructure that facilitates management of DIaK, which in turn allows users (a person with a PC connected to the Net) to execute “intelligent” functions based on DIaK available in the Net. Hence, the notion of achieving intelligence by defining systems as interconnected intelligent elements makes a lot of sense. This scenario is known as “distributed intelligence.”

Each intelligent element or IE (which in the case of the WWW it encompasses a PC and its user) has to be able to communicate in order to provide and obtain data and information that is suitable to meet a need (which provides context) and in a timely fashion (in order to attend to the present need). Each IE addressing a need must process data and information from within and from the Net. Processing of data and information embodies embedded knowledge in the form of algorithms, strategies, and approaches focused on achieving the functions that define intelligence. The concept of networked IEs representing a system does not imply that the IEs have to be physical entities. Some can be physical and some can be virtual, and many virtual IEs can share one processing element. Hence, one does not need to wait for a physical “intelligent sensor” to be commercially available to implement this paradigm.

Achieving intelligence in aerospace systems is slowly becoming possible. Researchers and engineers are developing technologies leading to achieving higher and higher DOI by addressing technologies such as intelligent sensors; networked sensors; integrated system health management; distributed intelligence; communications standards and protocols, architectures, taxonomies, ontologies, and standards for distributed intelligence; intelligent decision making based on models; collaborative intelligence to achieve missions in a robust and reliable manner, etc. Applications that demonstrate advances in these areas can be found in commercial aircraft, but more prominently in unmanned air vehicles (UAVs), military applications, homeland security applications, spacecraft headed to celestial bodies, and perhaps to some degree NASA’s spaceships in development (ARES I and V, and ORION).

This special issue includes a selection of papers addressing many of the areas crucial to achieving intelligence (mentioned in the previous paragraph). The papers constitute a balanced mix of theory and experiments, and cover civilian and military application areas in aerospace and aeronautics. The first paper, “Demonstration of Digital Pheromone Swarming Control of Multiple Unmanned Air Vehicles,” was selected as the Best Paper of the Conference. We hope that the reader will find this issue to be a valuable source of information on leading edge research that is aimed at achieving intelligence in aerospace systems; with low DOI implementations beginning now, but based on an infrastructure that permits augmentation of the DOI as better technologies become available.

References

[1]Albus, J. S., “Outline for a Theory of Intelligence,” *IEEE Transactions Systems, Man and Cybernetics*, Vol. 21, No. 3, May/June, 1991, pp. 473–509.

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Fernando Figueroa
Ella Atkins
Richard Doyle
Sanjay Garg
Lyle N. Long
Jim Neidhoefer
AIAA Intelligence Systems Technical Committee