ARTIFICIAL INTELLIGENCE: MILITARY APPLICATIONS

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Abstract

Artificial intelligence is an emerging teshnology that has recently attracted considerable attention. Many applications are now under development. The goal of artificial intelligence is focused on developing computational approaches to intelligent behavior. This goal is virtually covering all aspects of human cognitive activity. This paper endeavors to discuss what artificial intelligence is and the potential range of its applications with special reference to military.

INTRODUCTION

Artficial intelligence (AI) is considered by many to be one of the key technological innovations that will continue to shape the transformation of the modern society into the next century. Modern society has moved steadily from an industrially based economy to one that is dominated by the creation and processing of information.

Although AI has been studied academically since the late 1950's, the subjet has recently generated wider interest because commercial applications now seem to be practical. One major factor in the successful transition from academia to industry is the dramatic advances in computer hardware that have occurred in the last two decades. Computer prices and sizes have plummeted, whereas memory capacity and processing speeds have increased to the point that personal microcomputers today possess all the power of the mainframes used by AI researchers in the late 1950's and 1960's. Because AI applications tend to be computer-intensive, requiring a great deal of computer resources, the technological advances in the computer industry as a whole have increased the likelihood of successful commercialization.

The thrust of this study is to discuss AI with the special reference to military applications.

Definition

Although numerous definitions of AI are available[1], we will use the definition of Army Science Board (ASB). The ASB defines AI thus:

> A programmable machine exhibits artificial intelligence if it can incorporate abstraction and interpretation into information processing and make decisions at a level of sophistication that would be considered intelligent in humans[2].

Artificial intelligence is the study of intelligent behavior. Its ultimate goal is the theory of intelligence that accounts for the behavior of naturally occurring intelligent entities and that guides the creation of artificial entities capable of intelligent behavior[3].

Field of Study

Artificial intelligence is a field of study that encompases computational techniques for performing tasks that apparently require intelligence when performed by humans. Such problems include diagnosing problems in automobiles, computers and people; designing new computers, writing stories and symphonies, finding mathematical theorems, assembling and inspecting products in factories, and negotiating international treaties[4]. It is a technology of information processing concerned with processes of reasoning, learning, and perception.

Fundamental issues of artificial intelligence involve knowledge representation, search, perception and inference[5]. Knowledge can be

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[1] For various definitions of AI see: Avron Barr and Enward Feigenbaum, **The Handbook of Artificial Intelligence**, vol. 1, Stanford, Heuris Teach Press, p. 3; Patrick H. Winston, **Artificial Intelligence**, Reading, Addison - Wesley Publishing Co., 1977, p. 1; and Pat O. Clifton, **Artificial Intelligence A "User Friendly" Introduction**, Air University Press, Alabama, Marc 1985, p. 2.

[2] Barry J. Brownstein et al., "Technological assessment of future battlefield robotic applications", in **Procesedings of the army Conference on Application of AI to Battlefield Information Management**, U.S Navy Surface Weapons Center, White Oak, 1983, p. 169.

[3] Michael R. Genesereth and Nils J. Nilsson, **Logical Foundations of Artificial Intelligence**, Morgan Kaufmann Publishers, 1987, p. 1.

[4] Steven L. Tanimoto, **The Elements of Artificial Intelligence: An Introduction using LISP**, Computer Science Press, Rockville, 1987, p. 6.

[5] Steven L. Tanimoto, **Ibid.**, p. 6.

available in many forms such as collections of logical assertions, heuristic rules, procedures, and statistical correlations.

Search is key issue because it is usually easy to invent brute-force algorithms of creating explicit representations of knowledge from implicit ones.

The purpose of Artificial Intelligence

The most important purpose of AI is to increase man's understanding of reasoning, learning, and perceptual processes. This understanding is desirable for two reasons[6]: it is needed to build useful new tools and it is needed to achieve a more view of human intelligence than currently exists.

A deeper understanding of human intelligence and its limitations is extremely important, for it might lead to suggestions for partially resolving many of the political and religious disagreements in the world that currently pose a great threat to the human race.

Before we go into details on these basic ideas, it is illuminating to review the history of AI.

BACKGROUND

Artificial intelligence research has gone almost since the introduction of the digital computer. It is based on the idea that all intelligent activity can be formalized and described by some of computable function. That is, that all human intelligence can, in principle, be mankind by a digital computer[7].

Work in AI began in earnest in the 1950's, with great expectations that important successes would be achieved quickly.

By early 1960's, few practical applications of AI had emergeld. By the 1970's, research began to bear fruit. The approach that emerged from its success was to build more narrowly focused systems that used relatively simple problem solving methodologies but were very knowledge-intensive. These systems had large domain —specific knowledge bases and extensive procedural problem— domain— specific knowledge[8].

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[6] Steven L. Tanimoto, **Ibid.**, p. 7.

[7] Daniel Schutzer, **Artificial Intelligence: An Applications-Oriented Approach,** Van Nostrand Reinhold Company, New York, 1987, p. 8.

[8] Daniel Schutzer, **Ibid.**, p. 8.

As indicated in Table — 1, in the 1970's AI researchers began to capitalize on the lessons learned. New knowledge representation techiniques appeared. Search techniques began to mature. Interactions with other fields such as medicine, electronics and chemistry took place. Feasible approaches were demonstrated for language processing, speech understanding, computer vision, and computer programs that could perform like exports[9].

Table — 1. Developments in the decade of 1970's

Activities

* Feasible Approaches Demo'd for:
  - Language Processing
  - Computer Vision
  - Expert Systems
  - Speech Understanding
* New Knowledge Representation Techniques Appear
* Search Techniques Begin to Mature
* Interaction with Other Fields Takes Place

Lessons Learned

* Knowledge Central to Intelligence
* Future Complex Systems Provide Feasible

Source: William B. Gevarter, **An Overview of Artificial Intelligence and Robotics**, NASA Technical Memorandum 85836, NASA Scientific and Technical Branch, Washington, D.C., vol. 1, Part A, 1983, p. 9.

As Table — 2 indicates the decade of 70's set framework from which the successes of the 80's emerged. In the 80's expert systems proliferated. Dozens of prototype export systems were devised in such areas as medical diagnosis, chemical and biological synthesis, mineral and oil exploration, circuit analysis, tactical targeting, and equipment fault diagnosis[10].

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[9] William B. Gevarter, **An Overview of Artificial Intelligence and Robotics, NASA** Nechnical Memorandum 85836, NASA Scientific and Technical Branch, Washington, D.C., vol. 1, Part A, 1983, p. 8.

[10] William B. Gevarter, **Ibid.**, p. 9.

Table — 2. Developments in the 80's

Activities

* Expert systems proliferate
* Al goes commercial
  . Expert systems: RI, DIP — METER ADVISOR, MOLGEN
  . Natural language front ends — INTELLECT
  . Speech out
  . Vision systems
  . AI groups and companies from to exploit applications
  . LISP machines become available
* AI technology becoming codified
  . AI handbook
  . Individual technology texts: natural language, vision etc.
  . NSB/NASA overviews

Conclusions

* AI tools and systems become available
* Logis systems (heuristically guided) reemerge — PROLOG
* AI teshniques sufficiently perfected for early applications.

Source: William B. Gevarter, **An Overview of Artificial Intelligence and Robotics,** NASA Technical Memorandum 85836, NASA Scientific and Technical Branch, Washington, D.C., vol. 1, Part A, 1983, p. 10.

KEY ATTRIBUTES OF ARTIFICIAL INTELLIGENCE

More than anything else, AI represents a particular problem-solving-mind-set that differs from more traditional algorithmic-oriented approaches. AI research has concentrated on solving problems that are demonstrably solvable by human beings but for which no currently well-formulated, computationally feasible methodology exists. This class of problems includes[11]:

* How we learn
* How we play games?
* How we communicate with one another?
* How we perceive (see, speak, hear, listen, write)?
* How we create?

Thus AI has been concerned with human mental activities that are among the least well understood.

[11] Daniel Schutzer, **Ibid.**, p. 2.

The computer programs with which AI is concerned are primarily symbolic processes involving complexity, uncertainty, and ambiguity. These processes are usually those for which algorithmic solutions do not exit and search is required. Thus, AI deals with the types of problem solving and decision making that humans continually face in dealing with the world[12].

This form of problem solving differs markedly from scientific and engineering calculations that are primarily numeric in nature and for which solutions are known that produce satisfactory answers. In contrast, AI programs deal with words and concepts and often do not guarantee a correct solution- same wrong answers being tolerable as in human problem solving.

Table — 3 provides comparison between AI and conventional computer programs. A key characteristic of AI programs is "heuristic search". In complex problems the number of possible solution path can be enormous. Thus, AI problem solving is usually guided by empirical rules-rules of thumb-referred to as "heuristic"-which help constrain the earch[13].

Table — 3. AI — Conventional system comparison

Artificial Intelligence	Conventional Computer Programming
* Primarily symbolic processes	* Often primarily numeric
* Heuristic search (solution steps implicit)	* Algorithmic (solution steps explicit)
* Control structure usually separate from domain knowledge	* Information and control integrated together
* Usually easy to modify, update and enlarge	* Difficult to modify
* Some incorrect answers often tolerable	* Correct answers required
* Satisfactory answers usually acceptable	* Best possible solution usually sought

Source: William B. Gevarter, **An Overview of Artificial Intelligence and Robotics,** NASA Technical Memorandum 85836, NASA Scientific and Technical Branch, Washington, D.C., vol. 1, Part A, 1983, p. 1.

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[12] William B. Gevarter, **Ibid.,** p. 1.
[13] William B. Gevarter, **Ibid.,** p. 1.

BASIC ELEMENTS OF ARTIFICIAL INTELLIGENCE

Nilsson, a pioneer in AI, states the components of AI as (a) heuristic search, (b) knowledge representation, (c) common sense and logic, and (d) AI languages and tools[14].

Heuristic search

Much of early work in AI was focused on deriving programs that would search for solutions to problems. Every time one makes a decision. the situation is changed opening up new opportunities for further decisions. Therefore, there are always branch points. Thus, one of the usual ways of representing problem solving in AI is in terms of a tree, starting at the top with an initial condition and branching every time a decision is made.

As one continues down the tree many different decision possibilities open up, so that the number of branches at the bottom can get to be enormous for problems requiring many steps. Therefore, some way is needed to efficiently search the trees.

Knowledge representation

AI researchers discovered that intelligent behavior is not so much due to the methods reasoning, as it is dependent on the knowledge one has to reason with. Thus, when substantial knowledge has to be brought to bear on a problem, methods are needed to efficiently model this knowledge so that it is readily accessible. The result of this emphasis on knowledge is that knowledge representation is one of the most active areas of research in AI today. The needed knowledge is not easy to represent, nor is the best representation obvious for a given task.

Common sense reasoning and logic

AI researchers found that common sense is the most difficult thing to model in a computer. It was finally conculeded that common sense is low level reasoning, based on a wealth of experience. In acquiring common sense we learn to expect that when we drop something it falls, and in general what things to anticipate in everday events. How to represent common sense in a computer is a key AI issue that is unlikely to be soon solved.

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[14] N.J. Nilsson, "Artificial intelligence: engineering, science or slogan," **AI Magazine**, vol. 3, no. 1, Winter 1981/1982, pp. 2-9.

Another area that is very important in AI is logic. How do we deduce something from a set of facts? How can we prove that a conclusion follows from a given set of premises? Computational logic was one of the early golden hopes in AI to provide a universal problem solving method. However, solution convergence proved to be difficult with complex problems, resulting in a diminishing of interest in logic. Logic is now enjoying a revival based on new formulations and the use of heuristics to guide solutions.

AI languages and tools

In computer science, specific high level languages have been developed for different application domains. This also has been true for AI. Currently, LIPS and PROLOG are the principal AI programming languages.

APPLICATION AREAS OF ARTIFICIAL INTELLIGENCE

Based on these basic elements, Nilsson identifield four principal AI application areas[15]:

Natural language processing

Natural language processing is concerned with natural language front end to computer programs, computer-based speech understanding, text understanding and generation, and related applications.

Computer vision

Computer vision is concerned with enabling a computer to see-to identify or understand what it sees, to locate what it is looking for, etc.

Expert systems

Expert systems is perhaps the "hottest" topic in AI today. How do we make a computer act as if it was an expert in some domain? For example, how do we get computer to perform medical diagnosis or VLSI design?

Problem solving and planning

There are many problems for which there are no experts, but nevertheless computer programs for their solutions are needed. In addi-

[15] N.J. Nilsson, **Ibid.**, p. 6.

tion, there are some basic planning systems that are more concerned with soluiton techniques than with knowledge.

On the other hand, As they are listed in the Appendix, Gevarter summarizes the potential range of AI applications under four headings. Among these we will focus on military applications.

MILITARY APPLICATIONS OF ARTIFICIAL INTELLIGENCE

The impact of AI on military technology and tactics may be tremendous. We may see greather autonomy, sophistication and dispersion of weapons systems and personnel[16].

During the last few years AI technology-related activity within the military has increased dramatically. This heightened interest and expanding investment in AI may be attributed to a number of factors, in particular.

1. the very real progress AI technologies have been making and demonstrating at academic centers and in commercial applications;
2. the increasing complexity of modern — day military operations, brought about in great degree by significant advances in the speed and accuracy of sensors and weapons, coupled with the rapid growth in the amount of critical information to be produced, analyzed, and assimilated under severe time limited manpower; and
3. a growing awareness and acceptance by the military of the potential of AI technologies to help solve military problems[17].

The possible contributions of AI to defense span the breadth of military activities. Table — 4 relates 14 basic teschnologies to a number of military-problem areas. Applicability to seven generic military problem areas as well as a number of more specific task domains is indicated as either major or minor. That the matrix is quite dense is not surprising; each AI technology is applicable to a wide variety of military task areas, and each problem could profit from a number of AI techniques.

Note also that the generic problem entry "operations" is rated as a potential major application area of almost all of the AI technologies considered. The more specific military task areas enumerated in the table are not only primarily operations oriented, but many are vital components

[16] E.W. Martin, "Artificial Intelligence and Robotics for Military Systems", in **Proceedings of the army Conference on Application or artificial Intelligence to Battlefield Information Management,** U.S. Navy Surface Weapons Center, 1983, p. 3.

[17] **Encyclopedia of Artificial Intelligence,** Wiley, 1987, p. 604.

Table — 4. Military applications of AI technologies*

Defense Applications	AI Applications To													
	SİA	IA	SA	NSA	NLU	II	L	PC	RA	R	DS	UI	SD	IMR
R&D	x	x	x	0	x	x	0	0	x	x	x	x	0	x
Manufacturing	x	x	x	x	x	x	x	0	0	0	x	x		x
Operations	0	0	0	0	0	0	0	0	0	0	0	0	x	0
Maintenance	x	x	x	x	x	x	x	x	x	x	x	x	x	0
Logistics	x	x	x	x	x	x	x	0	0	x	x	x		0
Personnel		x	x	x	x	x		x	x			x		0
Training	x	x	0	x	0	x	0	x		x	x	0	x	x
Intelligence collection and surveilllance	x			x	x			x		x				x
Intelligence processing	0	0	x	x	x	x	x		x		0	x		x
Intelligence analysis and situation assessment			x	0	0	0	0	x	x		0	x		0
Sensor resaurce allocation							x	x	0		x	x		x
Force allocation			x	x	x	x	x	x	0		x	0		x
Force command and control	x	x	x	0	x	0	x	0	x		x	0	x	x
Route planning and navigation	x	x	x	x	x	x	0	0			x	x		x
Battle tactics			x	x	x	x	0	0			x	0	x	x
Targeting	0	0	x		x	x	x	x	0		x	x		x
Autonomous and semi autonomous vehicles	0	0	x	x		0	0	0	x	0	0	x	x	x
Avionics	x	x	x	x		0	x	x	x		x	0		
Electro. warf.	0		x	x	x	0	x	x	x		x	x		x
C^3 I Count. meas.	0	x	x	0	x	x	x	x	x		x	x		x
Communications	x		0	x	x	x	x	x			x			x
Network control			x			x	x	0			0	x		x
Information routting			x	x	0		0	x	x	0		0		
Information management and retrival	x	x	x	x	0	0	x	x	0		0			
Combat engineering and support		x	x		x	x		x	x	x	x	x		x

* Symbols: 0, major applicability; x minor applicability; SIU = Signal Understanding; IU = Image Understanding; SU = Speech Understanding; NSU = Signal Understanding; NLU = Natural - Language Understanding Generation; II = Information Integration; L = Learning; PC = Planning/Control; RA = Resource Allocation; R = Robotics; DS = Distributed Systems; UI = User Interfaces; SD = User Interfaces; SD = Software Development; IMR = Information Management Retreival.

Source: **Encyclopedia of Artificial Intelligence**, Wiley, 1987, p. 605.

in the critical operations area of command, control, communications, and intelligence (C^3 I).

It is hoped that AI will provide new methodologies for handling informaiton acquisition and processing problems which require les computional and communications resources than currently is the case, leading to getting the right information to the commander in time to act upon it.

One reason for this hope for AI is based on it's potential for more effective techniques of data compression. Such techniques may include the transformation of raw numerical data into domain of symbolic and semantic entities. This concept could be applied on all levels of battlefield information processing from individual sensors to comlex adaptive networks and data processing modes[18].

Although battlefield surveillance and target acquisition present some rather sophisticated challenges to the use of AI, it is noteworthy that some comlex problems of battlefield logistics can be also simplified by the use of AI. In fact, some of the greatest payoffs of AI as of this moment are in such areas as training, maintenance, operation of depots and so on[19].

Specific application areas

Three specific military areas targeted for initial technology applications are an autonomous land vehicle, an intelligent Pilot's Associate, and naval battle management[20].

Autonomous land vehicle

The development of the autonomous land vehicle, with active participation by the army, will emphasize computer vision and image understanding technologies. Ultimately, the addition of advanced AI reasoning techniques may allow the vehicle to not only sense and react but interpret its environment and than adapt its mission strategy correspondingly.

Initial work is concentrating on designing a vehicle that can automatically determine the path of a road and follow it. Eventually the vehicle must also be able to not only detect an obstacle in its path but

[18] A.B. salisbury, "Opening remarks on artificial intelligence," in **Proceedings of the Arm Conference on Application of Artificial Intelligence to Battlefield Information** U.S. Navy Surface Weapons Center, White Oak, AD - A - 139685, 1983, p. 7.

[19] A.B. Salisbury, **Ibid.**, p. 7.

[20] **encyclopedia of Artificial Intelligence**, Wiley, 1987, p. 604.

also determine its nature (e.g., a shadow, a traversable log, or a large boulder requiring a detour) and react accordingly.

Pilot's associate

In concern with the Air Force, the Pilot's Associate Projet is directed toward providing the pilot of a single-place fighter aircraft with the support and expertise of a "phantom flight crew". Rather than addressing the automation of conventional functions in an aircraft, the projet is aiming toward providing logical expertise in specified areas through the concept of an integrated cockpit.

Initially, the system is being conceived as a construct of four major interactive expert subsystems: a situation assessment manager, a tactical-planning manager, a mission-planning manager, and a system-status manager. Special emphasis is being placed on the pilot-vehicle interface, which will include advanced control, display, and automation techniques that utilize speech recognition, natural-language understanding, and voice synthesis.

Naval battle management

A goal of the battle management program, a joint effort with the Navy, is to demonstrate how AI technology, particularly expert systems and natural-language understanding, can contribute to the development of automated decision aids for the complex combat environment.

Five battle-management functions have been identified as initial application areas within fleet-command center operations. They include force requirements, capabilities assessment, campaign simulation, operations planning, and strategy assessment. These functions are well defined, yet complex, demanding, and labor intensive, requiring skill and expertise to perform and are thus promising candidates for export system decision aids.

As with the personnel they will support, expert systems developed for these applications will need to interact and cooperate with each other. Emphasis is also being placed on natural-language understanding, both as an interface between the expert systems and their users and as a means of automating the processing of the ever-increasing command-center massage traffic, which can expand 10-fold during crises.

Military operations, and in particular C^3I, posses significant characteristics that have not always been prominent in other AI application domains. One such characteristics is the time-critical nature of tactical decision making-the need for appropriate, real-time response to dynamic situations.

The deployment of increasingly complicated surveillance and weapons systems, both friendly and hostile, has compressed the time available for tactical decision making. Automated decision aiding (and ultimately automated decision making) under these conditions must emphasize efficient solution-space search and pruning techniques and consider finding the first solution that satissfies a given set of conditions or exceeds a specified threshold.

CONCLUSIONS

Computers were going to free mankind from the drudgery of processing information. Fifth generation computers, using AI techniques, are being promoted as the new solution to many of society's problems. AI is merely another problem-solving technology. Problems that cannot be clearly defined or identified using conventional methods are not going to be magically solved using AI. Artificial intelligence provides an alternate or supplementary means to work complicated tasks not only in the civilian world but also in the military. It seems that AI will be much used in military decision making in the future.

APPENDIX
APPLICATIONS OF ARTIFICIAL INTELLIGENCE

The potential range of AI applications is so vast that it covers virtually the entire breadth of human intelligent activity[21]. This appendix just summarizes some of the key applications. Generic applications are listed in Table 5. Examples of specific applications of AI are listed in Table 6. Potential functional applications for NASA are indicated in Table 7. The opportunities this opens up for NASA are listed in Table 8. Similar opportunities are available in many other public and private domains.

Table 5. Generic Applications of AI

Knowledge Management

* Intelligent data base access
* Knowledge acquisition
* Text understanding
* Text generation
* Machine translation
* Explanation
* Logical operations on data bases

[21] W.B. Gevarter, **Ibid.**, pp. 43-46.

Human Interaction

* Speech understanding
* Speech generation

Learning and Teaching

* Intelligent computer — aided instruction
* Learning from experience
* Concept generation

Fault Diagnosis and Repair

* Humans
* Machines
* Systems

Computation

* Symbolic mathematics
* "Fuzzy" operations
* Automatic programming

Communication

* Public access to large data bases via telephone and speech understanding
* Natural language interfaces to computer programs

Operation of Machines and Complex Systems

Autonomous Inteiligent Systems

Management

* Planning
* Scheduling
* Monitoring

Sensor Interpretation and Integration

* Developing meaning from sensor data
* Sensor fusion (Integrating multiple sensor inputs to develop high level interprations)

Design

* Systems
* Equipment
* Intelligent design aids
* Inventing

Visual Perception and Guidance

* Inspection
* Identification
* Verification
* Guidance
* Screening
* Monitoring

Intelligent Assistants

* Medical diagnosis, maintenance aids and other interactive expert systems
* Expert system building tools

Table — 6. Examples of Domain — Specific Applications of AI

Medical

* Diagnosis and treatment
* Patient monitoring
* Prosthetics
  — Artificial sight and hearing
  — Reading machines for the blind
* Medical knowledge automation

Science and Engineering

* Discovering
  — Physical and mathematical laws
  — Determination of regularities and aspects of interest
* Chemical and biological synthesis planning
* Test management
* Data interpretation
* Intelligent design aids

Industrial

* Factory management
* Production management and scheduling
* Intelligent robots
* Process planning
* Intelligent machines
* Computer — aided inspection

Military

* Expert advisors
* Sensor synthesis and interpretation
* Battle and threat assessment
* Automatic photo interpretation
* Tactical planning
* Military surveillance
* Weapon — target assignment
* Autonomous vehicles
* Intelligent robots
* Diagnosis and maintenance aids
* Target location and tracking
* Map development aids
* Intelligent interactions with knowledge bases

International

* Aids to understanding and interpretation
  — Goals, aspirations and motives of different countries and cultures
  — Cultural models for interpreting how others perceive
* Natural language translation

Services

* Intelligent knowledge base access
  — Airline reservations

* Air traffic control
* Ground traffic control

Financial

* Tax preparation
* Financial expert systems
* Intelligent consultants

Executibe Assistance

* Read mail and spot items of importance
* Planning aids

Natural resources

* Prospecting aids
* Resources operations
  — Driling procedures
  — Resource recovery guidance
* Resource management using remote sensing data

Space

* Ground operations aids
* Planning and scheduling aids
* Diagnostic and reconfiguration aids
* Remote operations of spececraft and space vehicles
* Test monitors
* Real - time replanning as required by failures, changed conditions or new opportunities
* Automatic subsystem operations

Table — 7. Potential Functional of AI in NASA

* Planning and scheduling
* Test and checkout
* Symbolic computation
* Information extraction
* Operations management
  — Monitoring
  — Control
  — Sequencing
* System autonomy
  — Subsystem management
  — Fault diagnosis
* Intelligent assistants

Table — 8. AI and NASA

AI Opens up an opportunity for NASA to

* Dramatically
  — reduce costs
  — Increase productivity
  — Improve quality

— Raise reliability
— Utilize facilities and people more effective
* Provide new mission capabilities
* Enable new missions
* Improve aerospace science and technology

By using AI techniques to increase human productivity and to help automate many activities previously requiring human intelligence.