INTELLIGENT SYSTEMS STRATEGIC TECHNOLOGY AREA

Presentation to
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12/7/98

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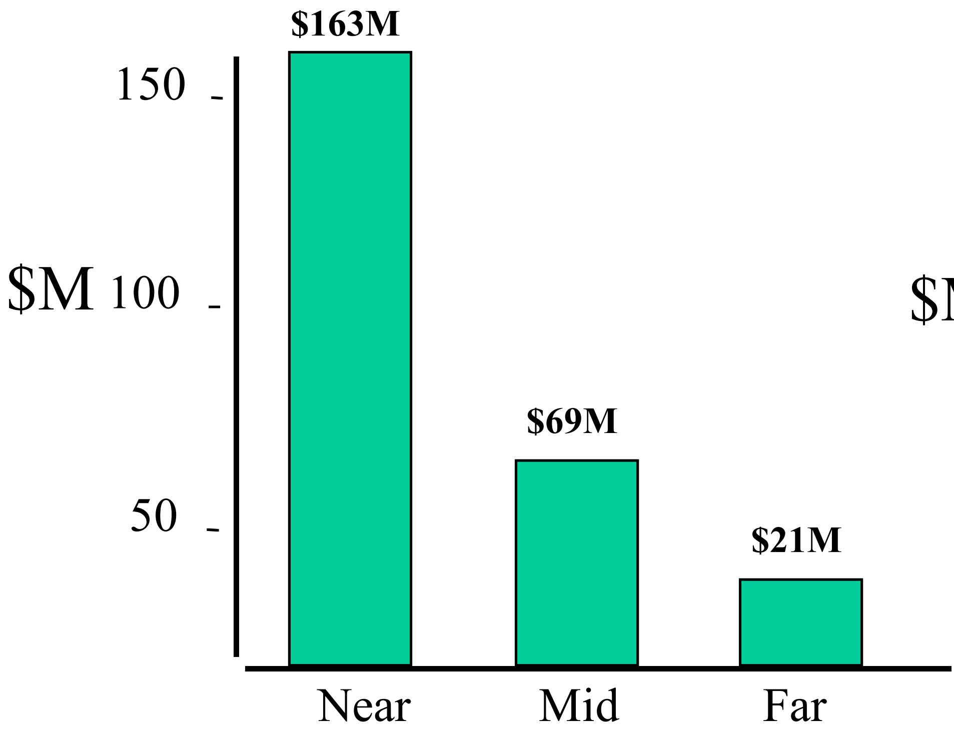
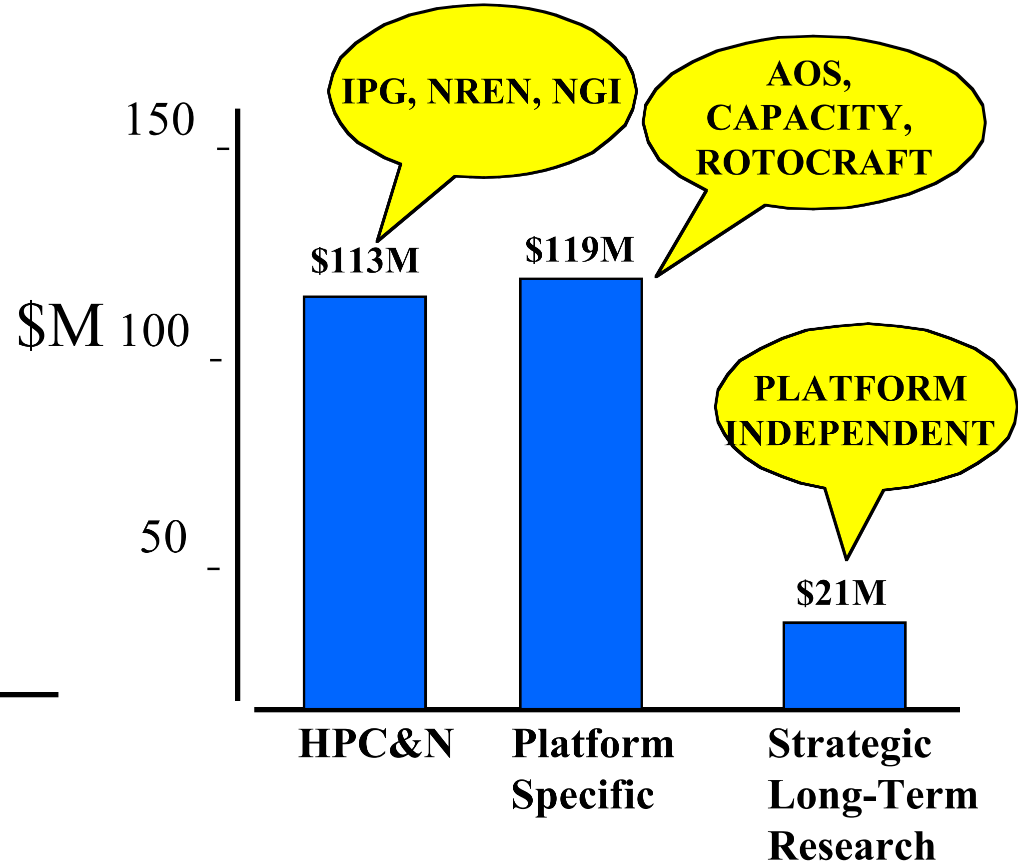
Intelligent Systems FY'98 Activities





- FY '98 Total $253 M
- % Far Term = 8.3%
- Excluding major industrial and onsite support contractors, 95% spent at NASA Centers

Intelligent Systems Major Investment Areas (Current)

Automated Reasoning

- Model-Based Reasoning
- Case-Based Reasoning
- High Assurance Software
- Biologically-Motivated (Biomimetic) Adaptive Systems
- Planning & Scheduling

$10M

Human-Centered Computing

- Knowledge Management and Institutional Knowledge Capture
- Optimized Displays
- Immersive / Haptic Environments
- Internet-Based Knowledge Representation
- Cognitive Architectures

$2M

Intelligent Systems for Data Understanding

- Geographically Distributed Computing
- Reconfigurable Computer Architectures
- Biologically-Motivated (Biomimetic) Computer/Component Architectures and SW
- Knowledge Discovery and Data Mining

$9M

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$10M+20 = $30M

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$2M + 15 = $17M ★

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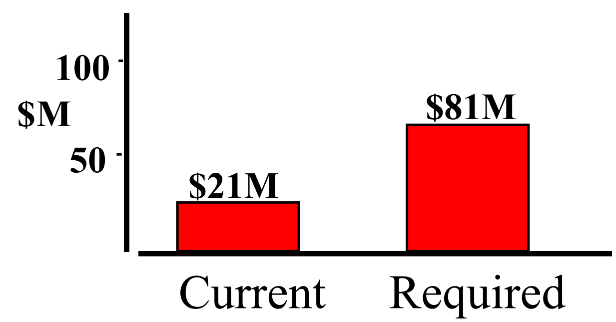
★ **Significant Investment to be targeted towards ISE**



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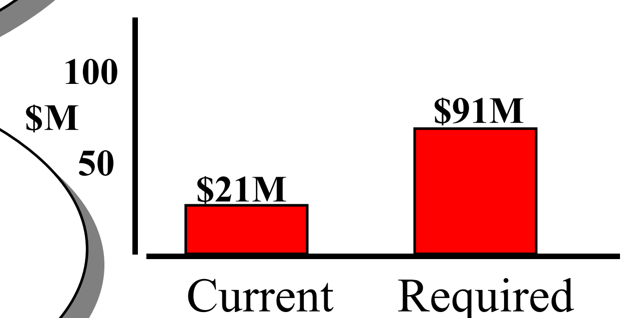
Revolutionary Computing

- Quanatum Mechanical Computing
- Neurally-inspired Computing
- Holographic Memory Devices
- Biological Computing

$<1M + 10 = $10M



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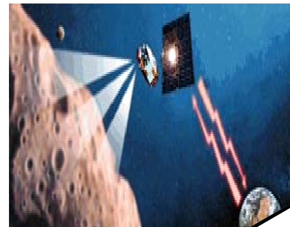
High Assurance Software

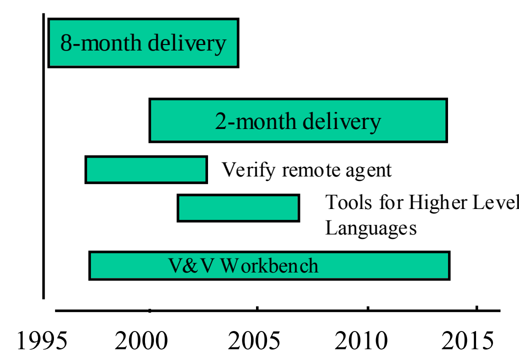


Example Application Missions:	Deep Space 1 (Now)	MDS-based missions (5 Yrs)	Interstellar precursors (15 Yrs)
Metrics			
Mission s/w deliv.	2-3 years	8 months	2 months
Errors/1000 lines at start of testing	40-80	7-14	.1-1
% lines hand-coded	95%	30%	5%
Program Size	~1000 lines	~10000 lines	~10M lines
V&V Effort	~1/2 man year	~1 man month	~30 seconds
Who does it	V&V experts	Programmers	Programmers
V&V target	Designs	Programs	Programs

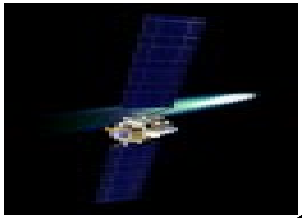
Objectives/Impact:

- Automated verification and validation of mission-critical software
- Development of a V&V workbench
- Software architecture & tools for model-based design, development and verification enabling order-of-magnitude reductions in development time, bugs, and cost.
- Impact: More rapid / lower cost response to new mission opportunities

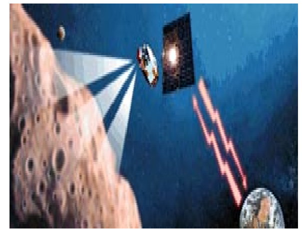
Schedule



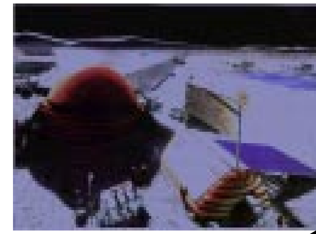
Model-based Reasoning for Remote Agent Architectures



Now



5 Yrs



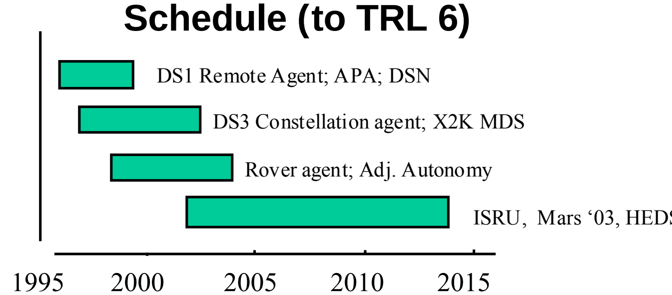
15 Yrs

	Now	5 Yrs	15 Yrs
Application Missions:	DS1, DSN, AirCam, APA	DS3, DS4, Mars 03	Mars ISRU, Origins
Metrics			
RAM Footprint	**30 MB**	**5 MB**	**1MB**
Replan rate	**8 hours**	**2 hours**	**5 minutes**
Unattended ops	**1 week**	**1 year**	**Fully adjustable**
Simplicity; Reuse	**5%; 20%**	**50%; 50%**	**90%; 70%**
Mission efficiency	**40% optimal**	**70% optimal**	**95% optimal**

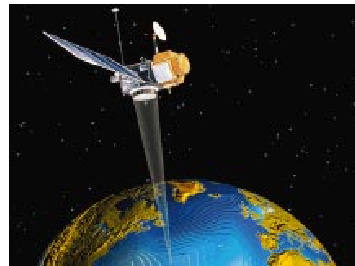
Objectives/Impact:

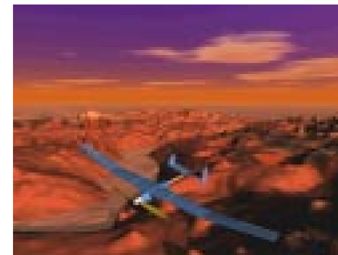
- **Agent architectures integrating autonomy technologies to increase autonomy of bases, spacecraft, vehicles and rovers**
- **Reduce training and operations costs**
- **Increase crew time for science**
- **Increase robustness and fault tolerance**
- **Gracefully change level of autonomy for human intervention**
- **Impact: Increased mission functionality, reliability, and efficiency at lower cost**

Schedule (to TRL 6)



Biomimetic SW/HW



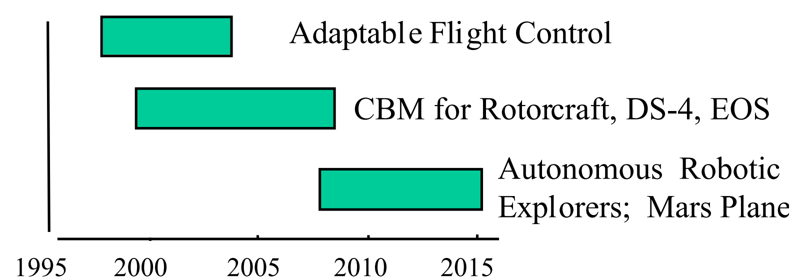


	Now	5 Yrs	15 Yrs
Example Application Missions:	**Adaptable Flight Control**	**CBM for Rotorcraft; DS-4; KDDM for EOS**	**Autonomous Robotic Explorers; HEDS/Mars ; Mars Plane**
Metrics			
Training Requirements	**Hours - days**	**Minutes - hours**	**Seconds - minutes**
Rough BNS Equivalent	**< 1000 neurons**	**< 100,000 neurons**	**> 1,000,000 neurons**
Neurally-inspired Chips	**< 5**	**> 10**	**> 200**

Objectives/Impacts:

- **SW and HW inspired by biologically-based computational strategies for advanced pattern recognition, sensor fusion, sensor-guided motor control, real-time adaptation**
- **Learning from experience**
- **cooperative strategies for independent agents**
- **Hybrid systems combining deterministic and quasi deterministic systems.**
- **Impact: autonomous control for maintenance, robotic exploration, flight control, data mining, and knowledge discovery**

Schedule



IS Program Plan Development

Four Central Elements

- Automated Reasoning/ Intelligent Mechanisms
- Intelligent Systems for Data Understanding
- Human-Centered Computing
- Revolutionary Computing

IS Program Plan Development

Mission Critical Application Areas

- Autonomous Spacecraft and Rovers
- Science Data Understanding
- Aviation Operations
- Intelligent Synthesis Environment
- Human Exploration of Space

IS Program Plan Development

Overview

- IS being developed as a new "Functional Office Initiative", with ARC as Lead Center
- Long-term research support for broad objectives
  - Faster, Better, Cheaper
  - Tech transfer, Commercial partners
- Broad Customer/Partner Base
  - All Enterprises
  - Other NASA initiatives/programs (ISE,IPG)
  - Other industry and government agencies (NSF, DARPA, DOE)

Summary

- Significant New Investment in Far-Term Intelligent Systems Strategic Research is Fundamentally Enabling for All Enterprise Missions
- Human-Centered Computing and Intelligent Systems for Data Understanding are <u>key</u> to success of ISE
- Intelligent Systems for Data Understanding is Crucial to Enable Science Understanding
- Automated Reasoning is Essential for Deep Space Exploration
- Revolutionary Computing Essential for Long-Term Mission Capabilities

Bottom Line:
Intelligent Systems Far-Term Strategic Research Requires Significant New Agency Investment

(backup slides follow)

Intelligent Systems - Enabled Critical Technology Capabilities

	5 Years	10 Years	15 Years
Aviation System Capacity	Free Flight Phase I Tool Integration	IMC Ops at VMC Rates	All Ops Beyond VMC Rules
Spacecraft Autonomy	Autonomous, Self-Commanding and Self-Protected Spacecraft	Curious and Self-Reliant Spacecraft	Cooperating Fleets for Sustained Virtual Presence
Earth Science Data Understanding	Data Archiving and Limited Mining Using 10's of Nodes	Data Mining of Multi-Platform Data Sets	Data Set Fusion / Mining from Multiple Platforms Using 100's of Distributed Nodes
Human Exploration	Fully Autonomous Life Support Systems	Fully Autonomous ISRU Systems	Exploration Data / LS Systems for Multiple Explorers

- **Single Intelligent Agent**
- **Individual Advisory Tools**
- **Hand-crafted SW**
- **Simple KDD tools**

$

- **Self-Adapting, Multiple Interacting Agents**
- **Interacting Advisory Tools for Distributed Teams**
- **Efficient / Cost-Effective SW Development Tools**
- **Sophisticated KDD tools**

Gap Analysis

	Today	5 Years	15 Years
Automated Reasoning	• Limited Intelligent Agents • Complex Collection of Non-Reusable Automated Languages and Methods • Loose Coupling of Autonomy HW/SW	• Adaptive, Knowledge-Based Agents • Increased Reuse, Rudimentary Toolkit for Automated Reasoning • Increasingly Fault-tolerant HW/SW	• Fully-Cooperative, Adaptive IAs • Maximized Reuse with Sophisticated Automated Reasoning Toolkit for Systems Engineers • SW-driven HW Physical Reconfigurability
Human Centered Computing	• Component Perspective • Desktop Metaphor • Individual Advisory Tools	• End-to-end Systems Perspective • Voice/Gesture Based Interfaces • Psychologically/Biologically Motivated Performance Support Systems	• Seamless Integration of Human / Machine Functions • Haptic / Immersive Interfaces • Tightly-Coupled Hybrid Methods Enabling Fully Integrated Human / Computer Interface
Intelligent Systems for Data Understanding	• Limited Utility KDD Tools • Early Statistical Analysis and Classification Methods (correlational) • Rudimentary Biologically motivated SW/HW • Limited Distributed Computing Environment	• Flexible, Multi-Use KDD Tools For Understanding Large Data Sets - ability to infer Causal Relations • Biologically-inspired SW/HW - real time learning • High-Bandwidth Sharing of Human Machine Resources	• Hybrid Adaptive Intelligent KDD Tools To Mediate Discovery/Understanding • Adaptive & Autonomous Sensor-guided Robotic Systems • Demand-Based, Shared, Flexible National IPG

Intelligent Systems Major Investment Areas
Leveraging Other Agency Investments

Automated Reasoning

- Model Based Reasoning
- Case Based Reasoning
- High Assurance SW
- Biomimetic Adaptive Systems
- Planning and Scheduling

- **NSF programs in computer science and DoD (ONR and DARPA) Programs in AI and biomimetics are the key programs to coordinate Investment strategy in this area.**
- **Discussions with NSF and DoD have resulted in preliminary Agreement to mutually leverage respective investments.**

Impact: NASA can leverage approx. $30M other agency investments

Intelligent Systems for Data Understanding

- Geographically Distributed Computing
- Reconfigurable Computer Architectures
- Biomimetic computer/component Architectures and SW
- Knowledge Discovery and Data Mining

- **Partnership and a specific MOU between NSF and ARC Developed in FY98 for future distributed computing investments.**
- **Discussions between ARC and DARPA have resulted in an agreement to partner in the area of biomimetic systems. Formalization of the MOU awaits NASA investment decision.**

Impact: NASA can leverage approx. $50M other agency investments

Human Centered Computing

- Knowledge Management and Knowledge Capture
- Optimized Displays/Interfaces
- Immersive/Haptic Environments
- Internet-Based Knowledge Representation
- Cognitive Architiectures

- **A formal MOU with NSF signed in FY98 to partner in area of Human Centered Computing. NASA and NSF are the primary sponsors of this work in the US.**
- **ONR has a focused research effort on-going in the area of Cognitive Architectures. A strong cooperative relationship exists between ARC and ONR.**

Impact: NASA can leverage approx. $20M other agency investments