

“The Future of Ocean Innovation”

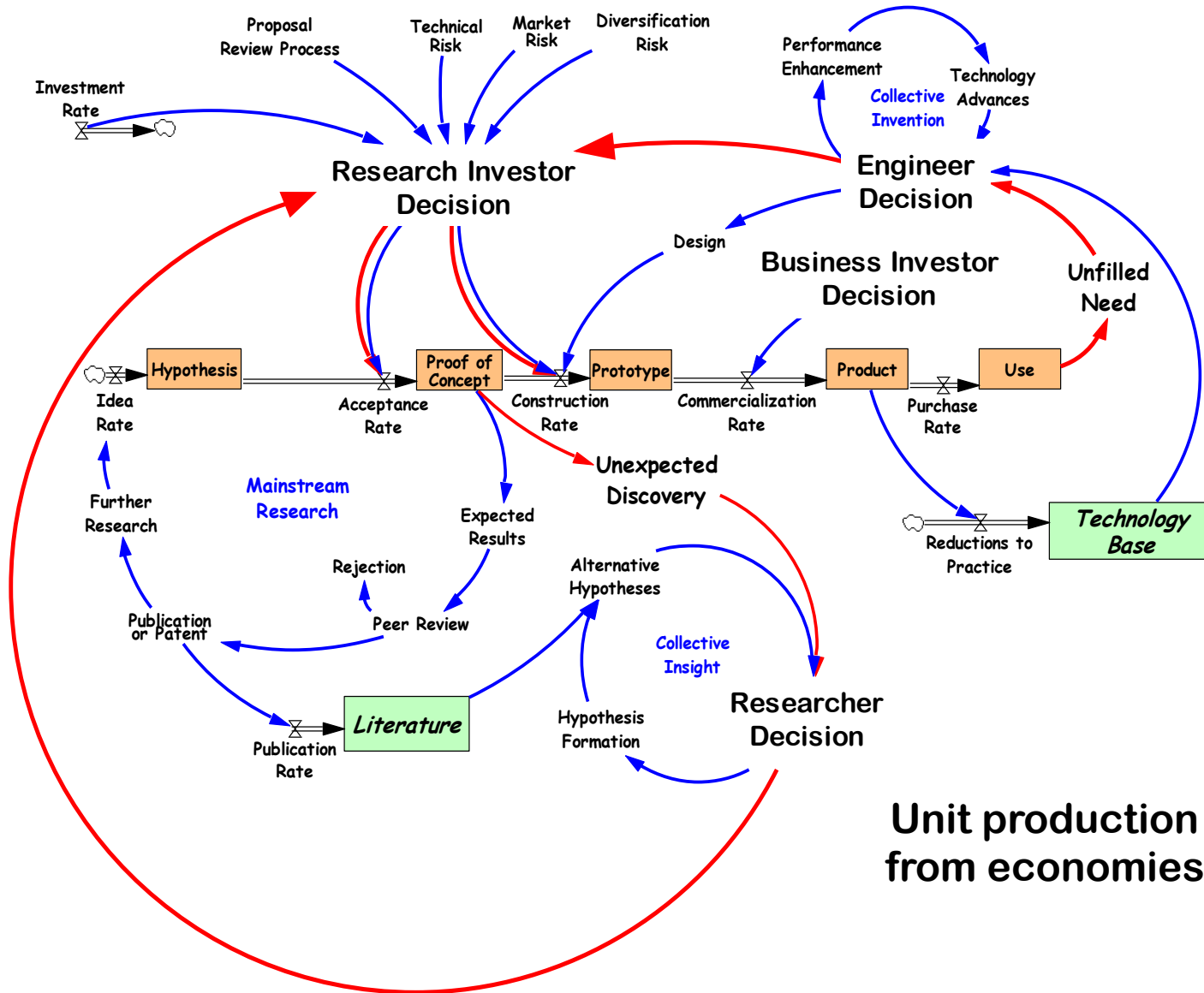


Thomas B. Curtin

18 July 2019

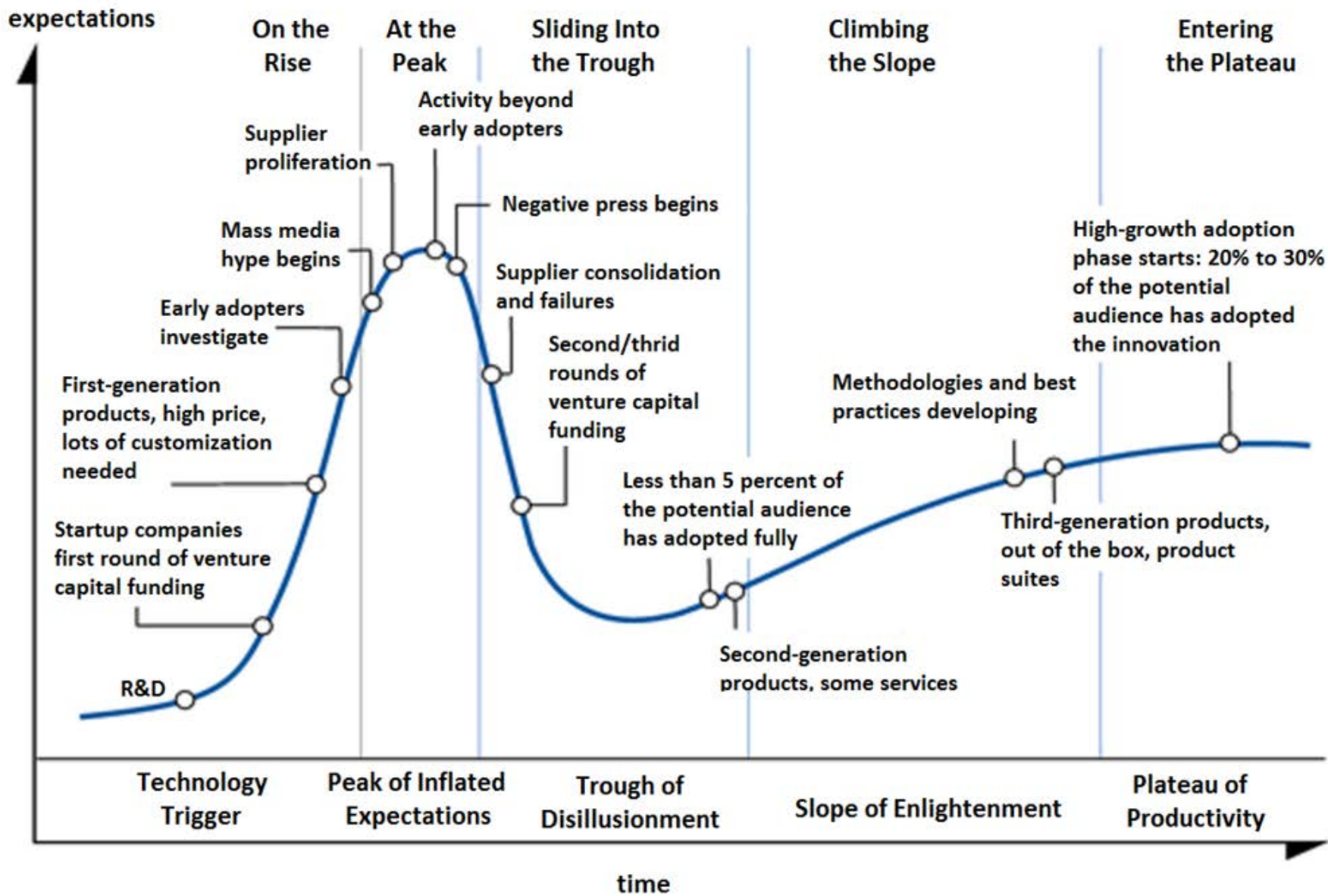
tcurtin@sloan.mit.edu

Return on Investment (Risk)

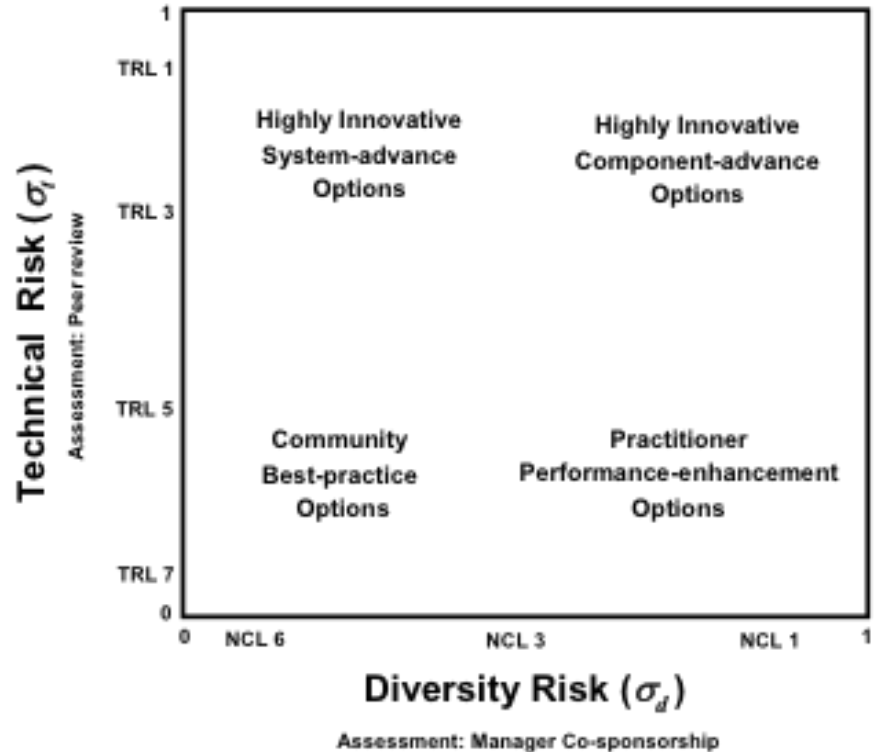
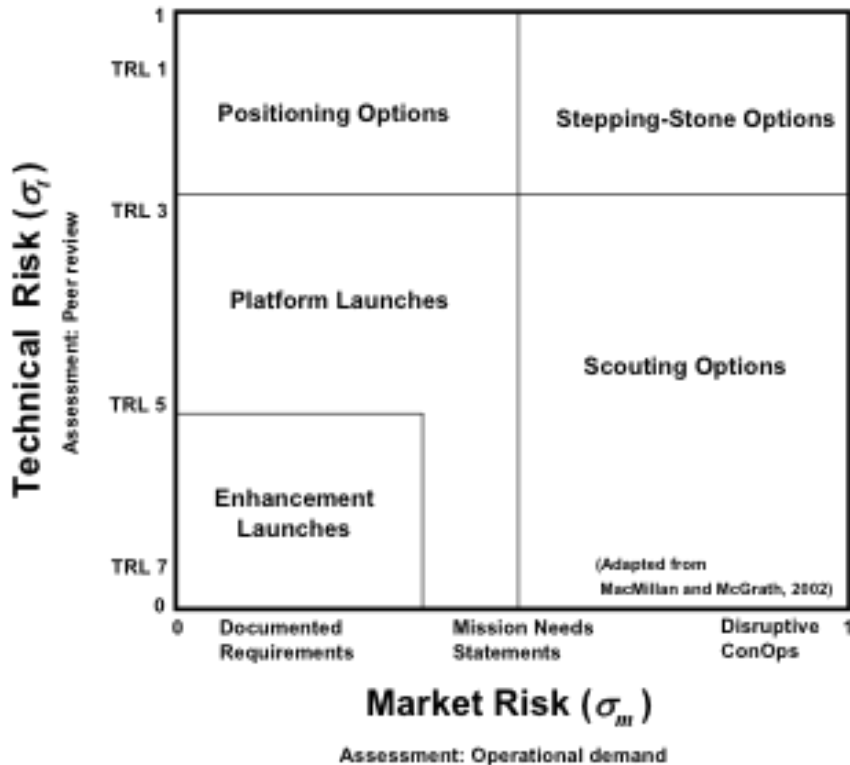


Unit production benefits from economies of scale

Innovation itself does not scale well because it is a contact sport



Options in Risk Space

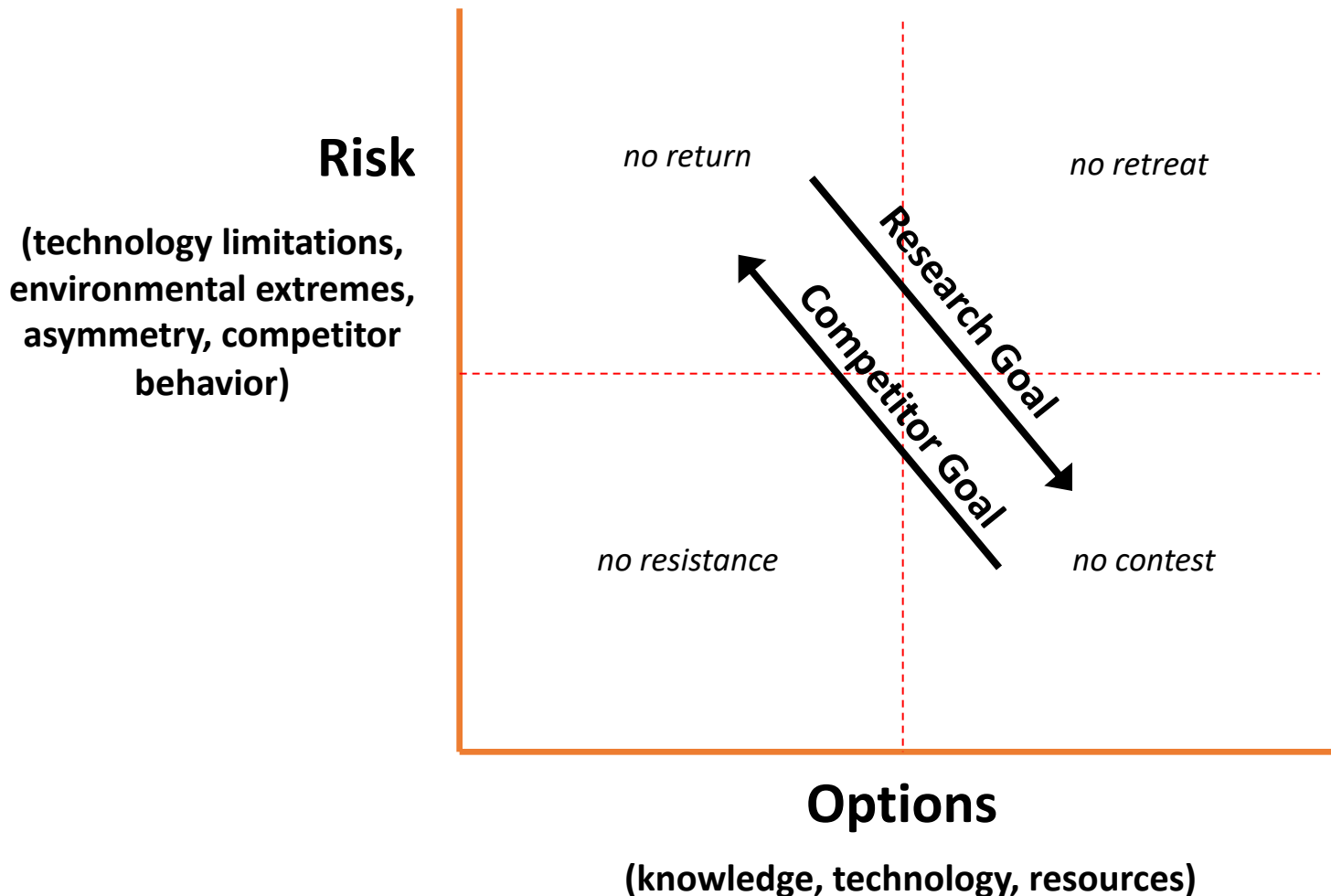


The magnitude of the risk vector is defined as the Volatility Index.

Volatility Index		
Technical Risk	0.500	σ_t
Market Risk	0.500	σ_m
Diversity Risk	0.500	σ_d
Volatility Index	0.866	$ \sigma $

The Deliverable Challenge

Provide Options for Uncertain Multiple Futures



$$C = S N(d1) - X e^{-rT} N(d2)$$



Robert M. Taylor in 1999. (DOUGLAS BENEDICT/THE MORNING CALL)

Robert Taylor

1934-2019

Mr. Taylor was not strictly an inventor, but as a research director at federal agencies and private research centers he had a knack for finding the right people and ideas to make the digital revolution possible. In the 1960s and 1970s, he had a direct effect on the invention of the computer mouse, the personal computer and the Internet itself.

Asked by a Rolling Stone reporter in 1972 to describe his job, Mr. Taylor said, “It’s not very sharply defined. You could call me a research planner.”

Excerpted from Matt Schudel, The Washington Post

In 1999, Mr. Taylor was awarded the National Medal of Technology by President Bill Clinton.

Early Stage Best Practices Learned from ONR/ARPA

Vision

- Focus on the longest-term, riskiest ideas and on problems unique to government. ²
- Define the vision, sell the vision to upper management and the research community; then buy the research. ⁴
- There is no substitute for a persistent champion.
- Maintain a coherent vision over a long period of time.

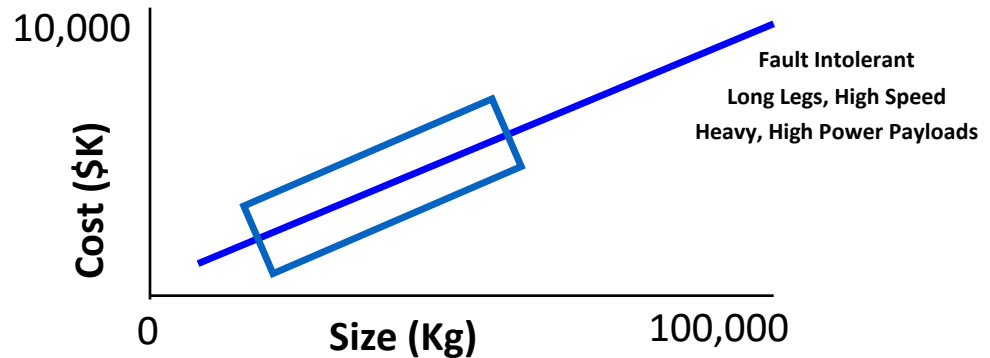
Goals

- Reduce ocean mapping error, improve predictive skill
- Monitor/control the littoral, undersea battlespace
- Produce COTS, affordable new tools to aid tactical decisions
- Capitalize on technology advances, commodity developments

Required Capabilities

- 3-Dimensional, Large Aperture
- Adaptive Resolution
- Sustained Presence
- Real time Control
- Energy, Bandwidth Management
- Robust to Unit Failure

Multiple Platforms

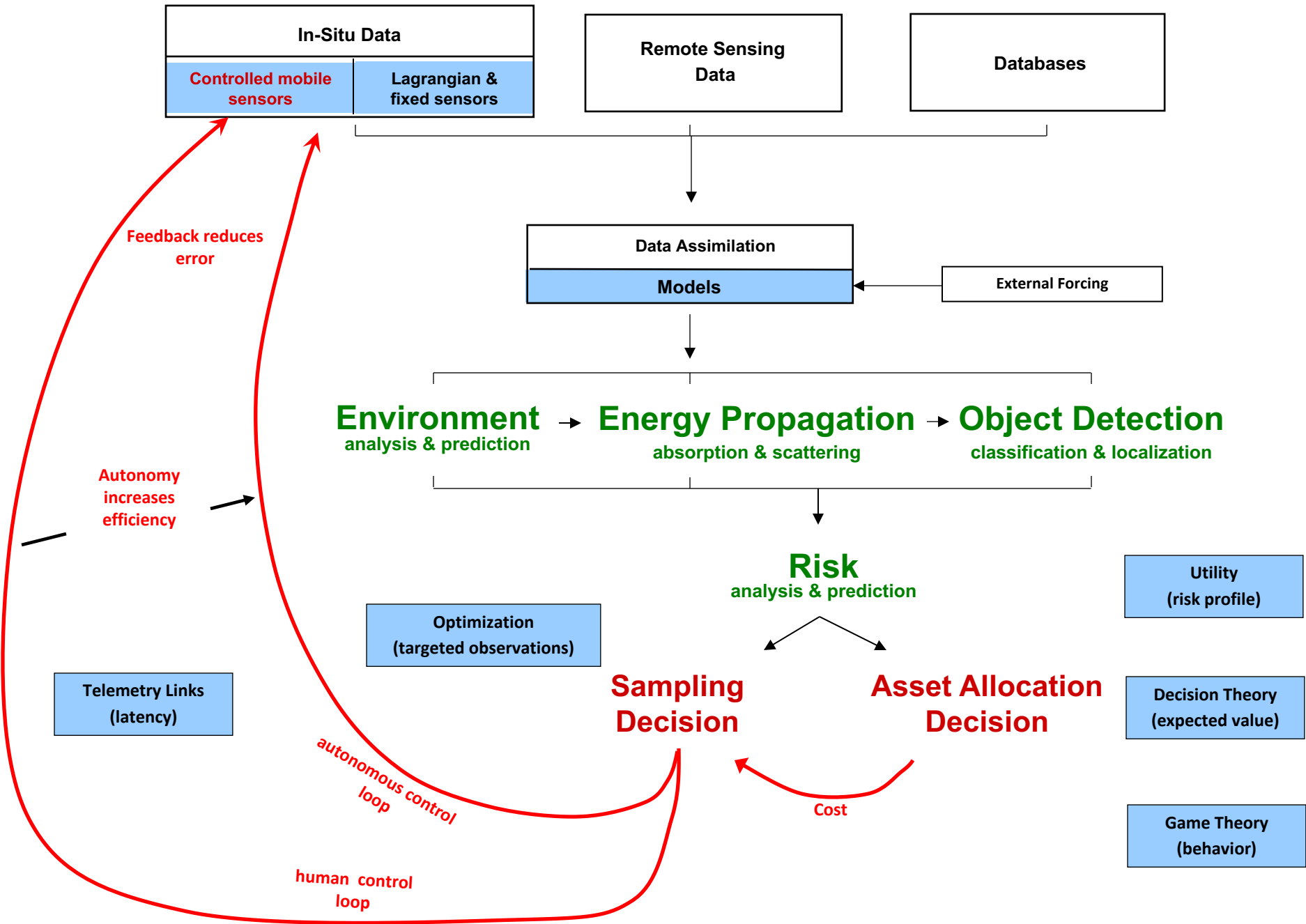


Autonomous Ocean Sampling Network

AOSN

Distributed Cells in a Volume

Cell nodes: sensors, communication, energy, intelligence, mobility



True Ocean

Fidelity

1

0

1800

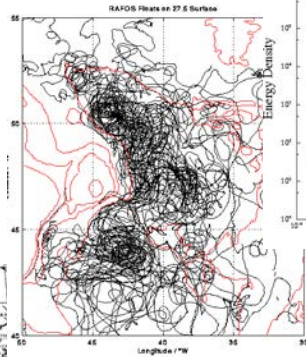
1900

2000

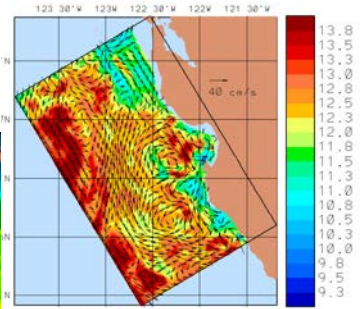
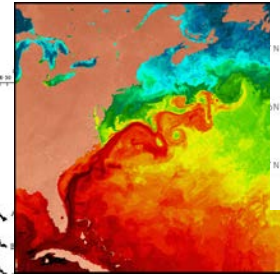
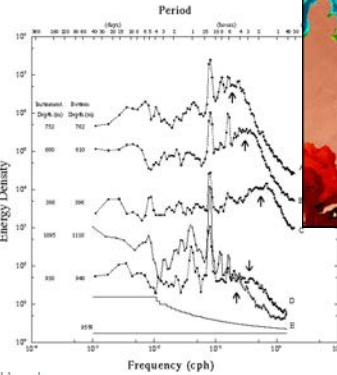
Observed / Estimated Ocean



Early chart showing the Gulf Stream

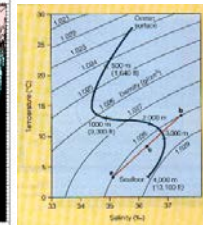
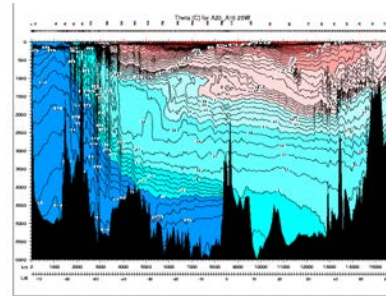


Nansen bottle



12:00:00Z 21 Aug 2006

Bathythermograph



SO FAR float

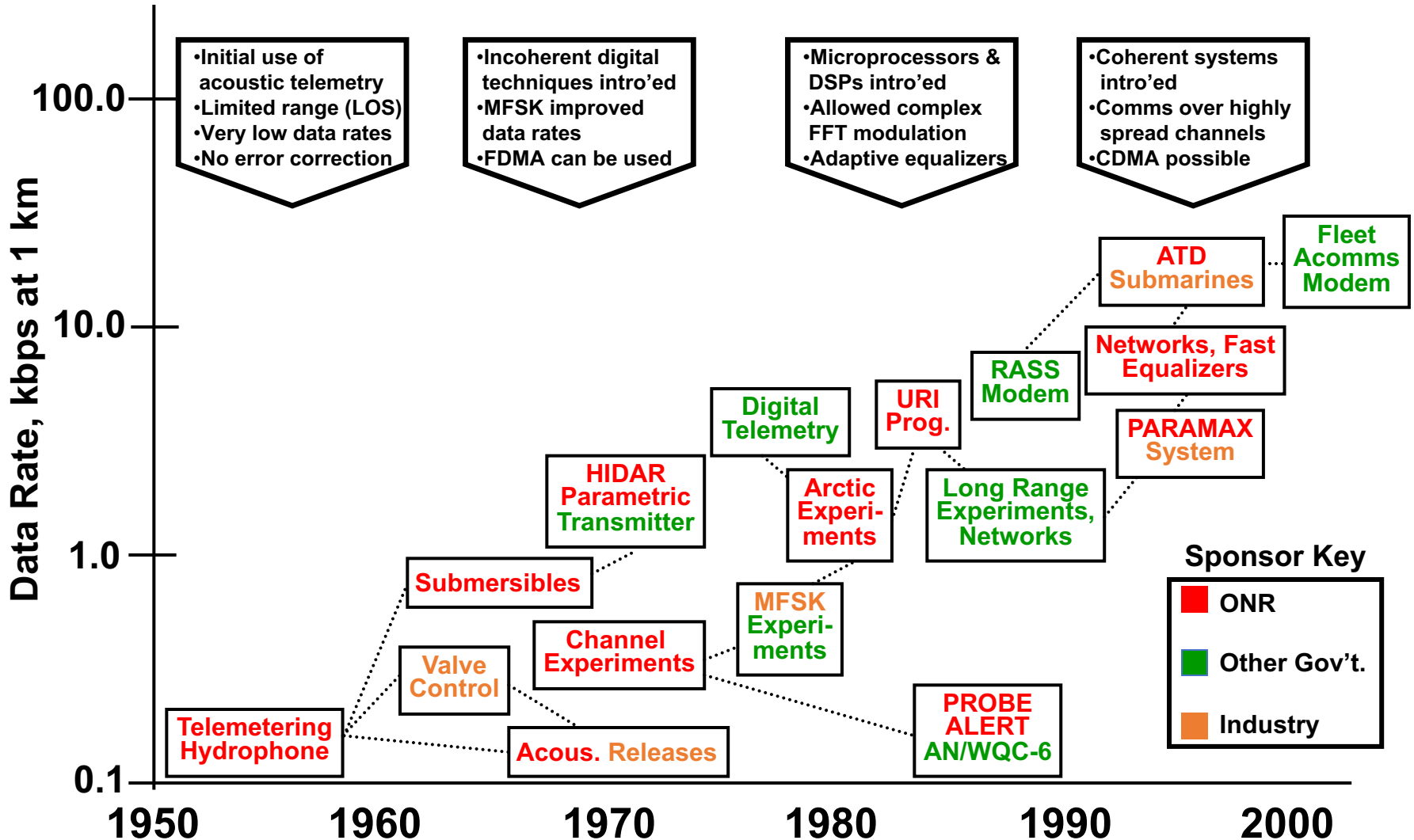
Mooring

Satellite

Autonomous Vehicle

Acoustic Comms S&T History

Enabling Technological Milestones



Persistence
(weeks)

Enabling Technologies

18

12

6

1

Color Key

S&T Experimentation

Publication

Operational Experimentation

Operational Transition

Commercialization

Global Positioning System
Iridium satellite comms
Orbcom satellite comms
Low power microprocessors

Lithium batteries

Deep Convection
Experiments (Seaglider,
Lab Sea)

Coastal Current Experiments
(Seaglider; CA, WA, AK Coasts)
(Slocum; NJ)

Thermal Glider Tests
(Slocum, Bermuda)

Cape Cod to Bermuda
(Spray, North Atlantic)

Monterey Bay 2006 (Spray,
Slocum, Seaglider, Liberdade, X-
Ray; Monterey Bay)

AOSN-II Adaptive Sampling
Experiments (Slocum, Spray;
Monterey Bay)

TASWEX-04 Demo
(Seaglider, East
China Sea)

SHAREM
148 Demo
(Slocum,
WestPac)

RIMPAC-04 Demo
(Seaglider, Hawaii)

NAVO Demo
(Spray, FL)

Adaptive Sampling Experiments (Slocum,
NJ)

NAVO WestPac
Demo (Slocum,
Philippine Sea)

AOSN Glider Development (Slocum, Seaglider,
Spray)

Flying Wing Prototype Tests
(Liberdade, San Diego)

Littoral Battlespace
Glider Navy
Acquisition

Slocum Paper
(Oceanography)

AOSN Paper
(Oceanography)

AOSN Special Issue
(IEEE/JOE)

Glider System
Study

AOSN Special
Issue (DSR)

Webb Slocum
Production

Bluefin
Licenses
Spray

APL/UW
Fabrication
Center

iRobot
Licenses
Seaglider

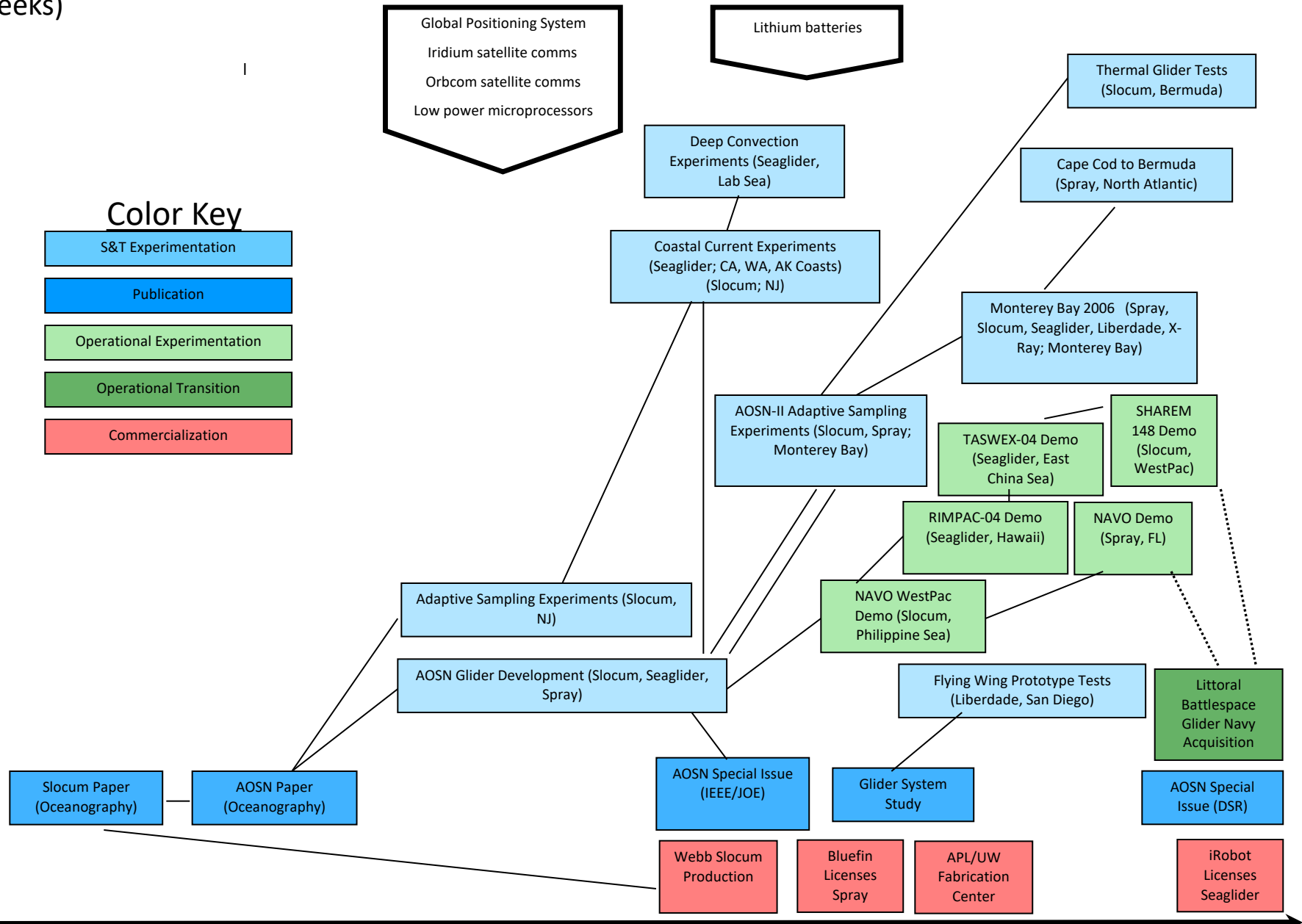
1990

1995

2000

2005

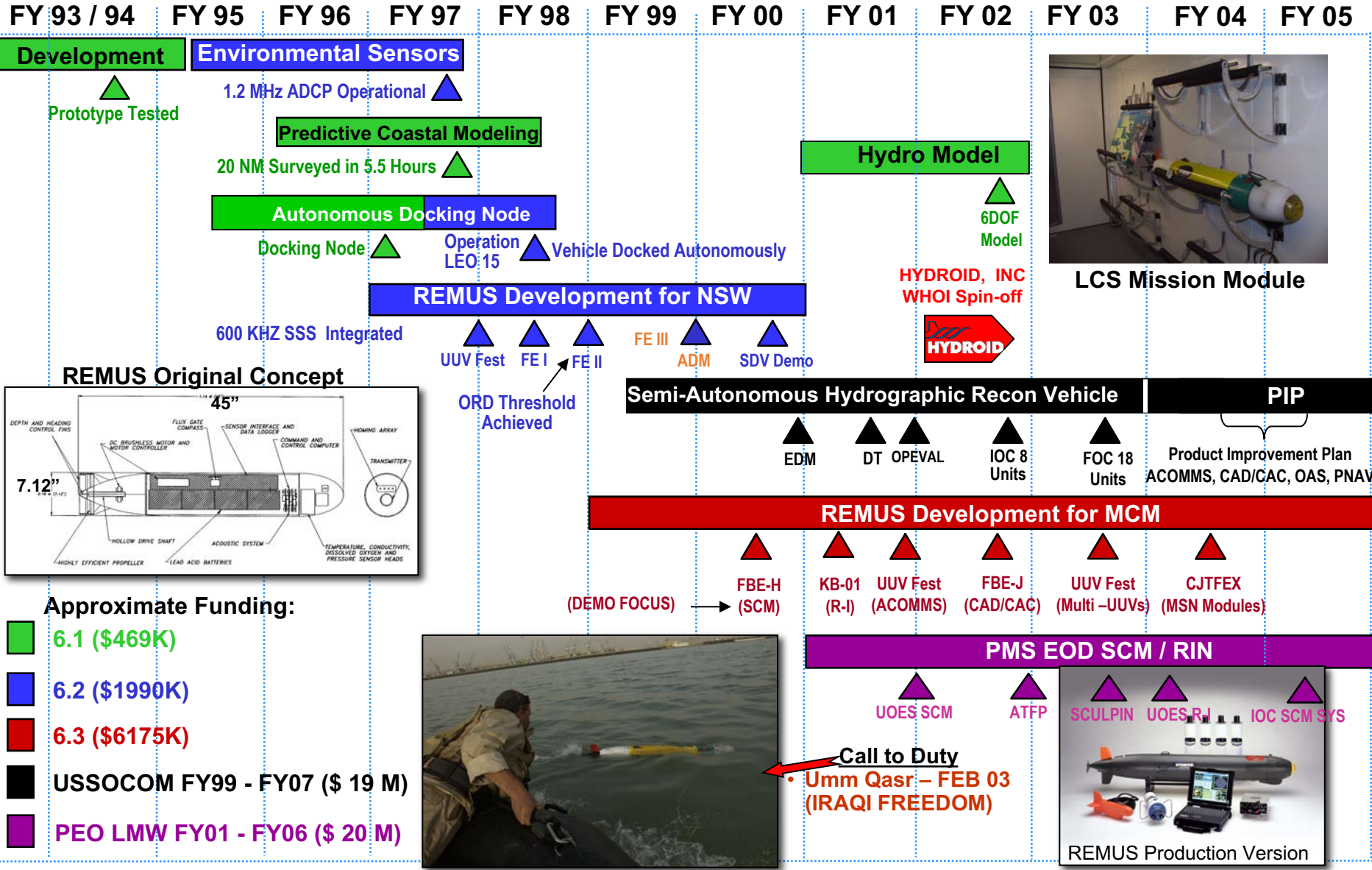
Figure 5



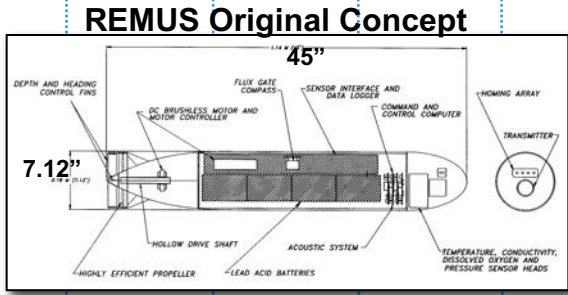


REMUS

Concept, Development, Transition, Commercialization, War



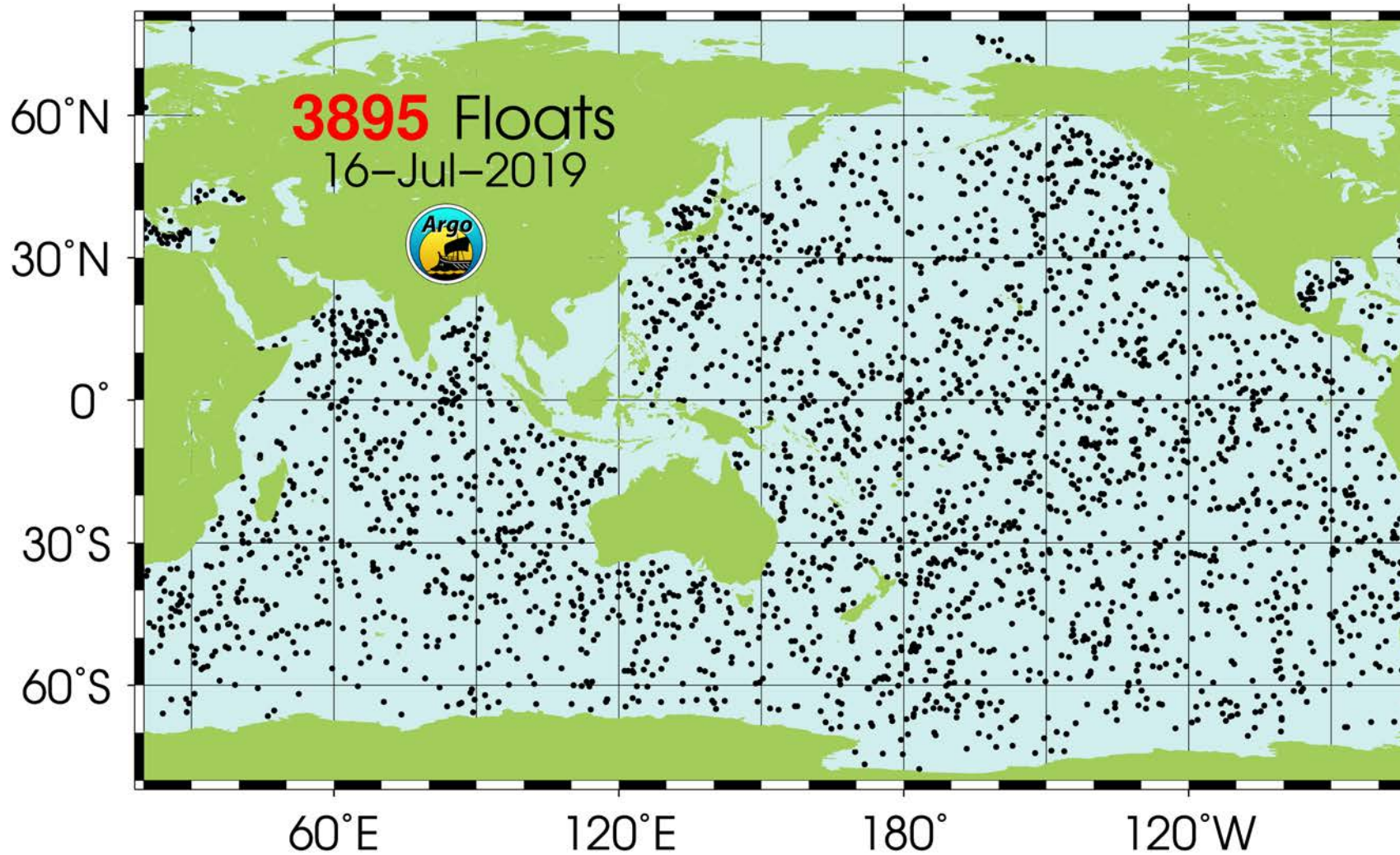
LCS Mission Module

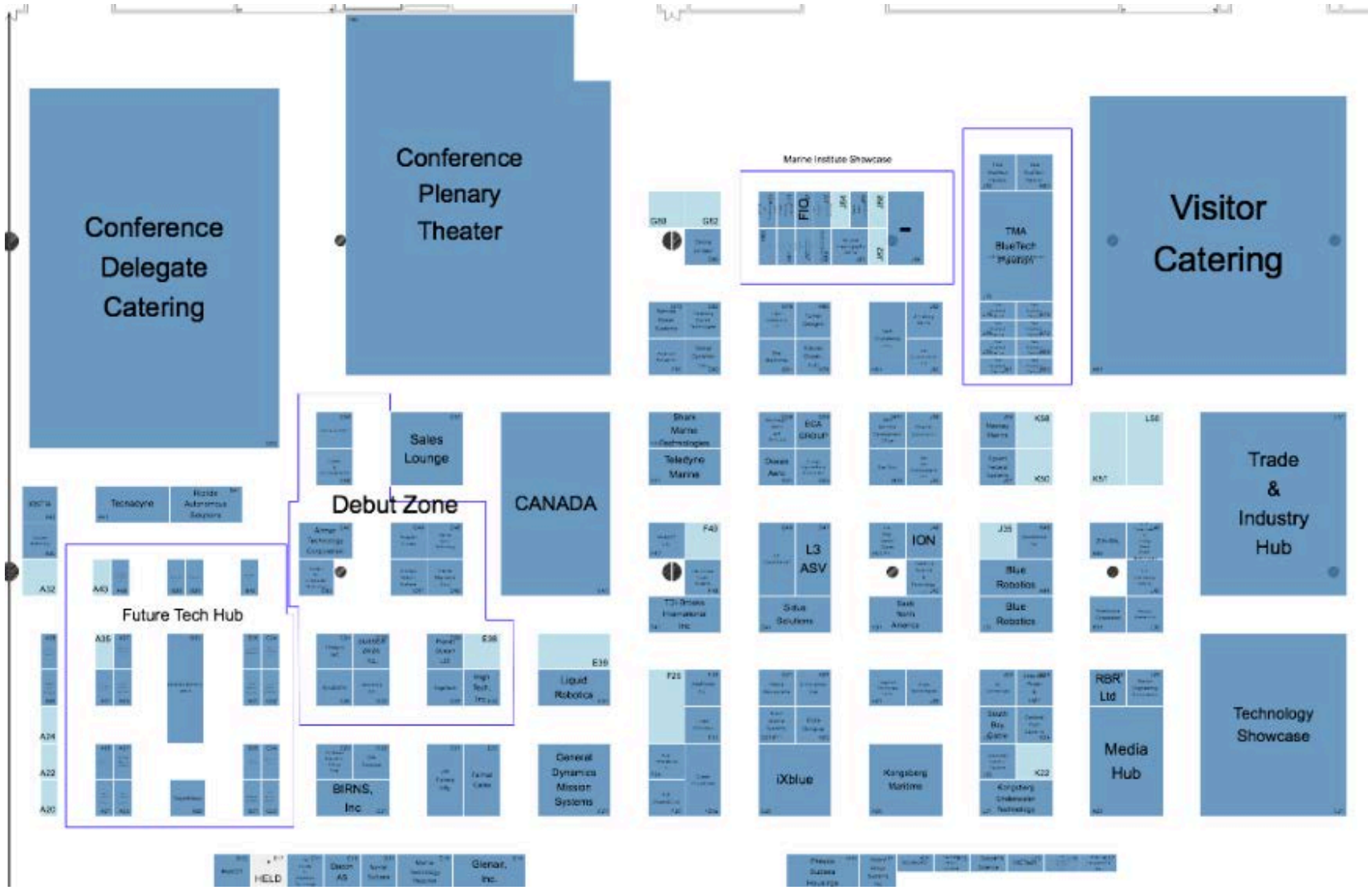


- Approximate Funding:**
- 6.1 (\$469K)
 - 6.2 (\$1990K)
 - 6.3 (\$6175K)
 - USSOCOM FY99 - FY07 (\$ 19 M)
 - PEO LMW FY01 - FY06 (\$ 20 M)



REMUS Production Version





Conference Delegate Catering

Conference Plenary Theater

Visitor Catering

Debut Zone

CANADA

Future Tech Hub

Marine Institute Showcase

Trade & Industry Hub

Technology Showcase

Media Hub

HELD

Pharos Systems

☆	-	J09
☆	Advanced Navigation	F81
☆	Aimar Technology Corporation	C40
☆	American Cargoservice, Inc.	L17
☆	Apium Swarm Robotics	C32
☆	Armstrong Marine	J62
☆	Beringia Enterprises LLC	A37
☆	BIRNS, Inc	C21
☆	Blue Robotics	J31 K44
☆	BlueLink	B36 B38
☆	Blueprint Lab	C24
☆	Blueprint Subsea	C49
☆	Boats and Harbors	A26
☆	Boston Engineering Corporation	L28
☆	CANADA	E41
☆	Cardinal Point Captains	K24
☆	CDIP/SCCOOS	H89
☆	CICESE, Research Center in Enseña...	H81 H83
☆	Coda Octopus	H22
☆	Comex Innovation	B25
☆	Conference Delegate Catering	C80
☆	Conference Plenary Theater	F60
☆	CR Encapsulation Ltd	J60
☆	Dacon AS	C15
☆	DBV Technology - Sonatech	A21 A23
☆	De Regt Marine Cables BV	H41
☆	DECK Marine Systems	B31
☆	DeepSea Power & Light	K28
☆	Del Mar Oceanographic LLC	J50
☆	DEMONSTRATION AREA	B30
☆	Dimensional Eye	H24
☆	Dolphin Acoustic Modems	A33
☆	ECA GROUP	G58
☆	EdgeTech	D31
☆	Engineered Syntactic Systems	J23
☆	Falmat Cable	E20
☆	Fibernetics LLC	A31
☆	Fiberpro INC	C31
☆	FIO	H87
☆	FLUIDION	C30
☆	General Dynamics Mission Systems	E21
☆	Geodevice LLC	D30

☆	Glenair, Inc.	E11
☆	Global Dynamix Inc.	G60
☆	GMSS & GEOSURVEYS	C48
☆	HCTech	L13
☆	HELD	B17
☆	High Tech, Inc.	E30
☆	Hydro Group Systems Inc	J11
☆	HydroMap Geomatics Ltd	A49
☆	Igloo Innovations Inc.	C34
☆	Imagenex Technology Corp.	H21
☆	IMarEST	B13
☆	Innerspace Corporation	K31
☆	Institute of Oceanology, CAS	H71
☆	International Ocean Systems	F48
☆	ION	J48
☆	IOSTIA	A42
☆	Irish Maritime Development Office	H51
☆	iXblue	G20
☆	JW Fishers Mfg	D21
☆	Klein Marine Systems, Inc.	G21a
☆	Kongsberg Maritime	H20
☆	Kongsberg Underwater Technology	J21
☆	KW Designed Solutions Ltd	L15
☆	L3 ASV	G47
☆	L3 OceanServer	G49
☆	Linden Photonics	F21
☆	Liquid Robotics	E31
☆	Loggerhead Instruments	B35
☆	MacGregor RAPP and TRIPLEX	G59
☆	Mackay Marine	J59
☆	Marine Magnetics Corp	D40
☆	Marine Sonic Technology	D48
☆	Marine Technology Reporter	D15
☆	Media Hub	K25
☆	National Oceanography Centre	J80
☆	Norbit Subsea	D11
☆	NOVACAVI	K11
☆	Ocean Aero	G51
☆	Ocean Frontier Institute	H73
☆	Ocean Innovations	F20a

☆	Olis Robotics	D22
☆	Orcina Limited	G80
☆	Outland Technology	A30
☆	Phoenix International	L30
☆	Planck Aerosystems	G21
☆	Planet Ocean Ltd	D39
☆	Polymer Corporation	J58
☆	Prevco Subsea Housings	H11
☆	RadExPro seismic software	K13
☆	RBR Ltd	K29
☆	Remote Ocean Systems	G70
☆	Riptide Autonomous Solutions	B41
☆	RJE International Inc.	F24
☆	RJE Oceanbotics	F20
☆	Robotic Ocean, LLC	H78
☆	Rowe Technologies	J28
☆	RV Zephyr/Outbound Marine	A25
☆	Saab North America	H31
☆	Sales Lounge	C51
☆	Scoot Science	K15
☆	Scripps Institution of Oceanography...	J70
☆	Sea Machines	G61
☆	Sea Technology magazine	A28
☆	SeaDrone Inc.	F23
☆	Shark Marine Technologies	F53
☆	Sidus Solutions	G41
☆	Society for Underwater Technology	C43
☆	Sonotronics Inc	K48
☆	Souriau-Sunbank	C54
☆	South Bay Cable	J25
☆	Southwest Electronic Energy Corp.	C23
☆	Spirent Federal Systems	J51
☆	Star-Oddi	H50
☆	Strategic Robotic Systems	C41
☆	SUBSEA 20/20, Inc.	D32
☆	Subsea Supplies/Eaton Interconnect	G50
☆	Surfbee Marine Robots	A27
☆	Swift Engineering Inc.	H61
☆	TDI-Brooks International Inc	F41
☆	TE Connectivity	J29
☆	Technology Showcase	L21
☆	Tecnadyne	A41

☆	Texas A&M University	J86
☆	ThayerMahan	B20
☆	The Society for Underwater Technol...	C11
☆	The University of Southern Mississippi	J72
☆	Think Sensor Research Inc.,	C20
☆	TMA BlueTech Pavilion	J61 J
☆	Trade & Industry Hub	L51
☆	Trelleborg Applied Technologies	G62
☆	Tritech International Ltd.	G79
☆	Turner Designs	H80
☆	U.S. Department of Energy Water Po...	L48
☆	Underwater Systems, Inc.	B40
☆	US Commercial Service	L40
☆	Valeport Ltd	F47
☆	Visitor Catering	K61
☆	Wieland BlueSea	B21
☆	ZUNIBAL	K49



- 1. Amador Valley High School**
Pleasanton, California, USA
- 2. Arizona State University Polytechnic**
Mesa, Arizona, USA
- 3. Beaver Country Day School**
Chestnut Hill, Massachusetts, USA
- 4. California Institute of Technology**
Pasadena, California, USA
- 5. California State University, Los Angeles**
Los Angeles, California, USA
- 6. Carnegie Mellon University**
Pittsburgh, PA, USA
- 7. Cornell University**
Ithaca, New York, USA
- 8. Duke University**
Durham, North Carolina, USA
- 9. Eastern Mediterranean University**
Famagusta, North Cypress, Turkey
- 10. École de Technologie Supérieure**
Montreal, Québec, Canada
- 11. Embry-Riddle Aeronautical University**
Daytona Beach, Florida, USA
- 12. Far Eastern Federal University**
Vladivostok, Russia
- 13. Federal University of Rio de Janeiro**
Rio de Janeiro, Brazil
- 14. Georgia Institute of Technology**
Atlanta, Georgia, USA
- 15. Gonzaga University**
Spokane, Washington, USA
- 16. Harbin Engineering University**
Harbin, Heilongjiang, China
- 17. Harvey Mudd College**
Claremont, California, USA
- 18. iHub**
Cairo, Egypt
- 19. Indian Institute of Technology, Bombay**
Powai, Mumbai, India
- 20. Indian Institute of Technology, Kanpur**
Kanpur, Uttar Pradesh, India
- 21. Kasetsart University**
Bangkok, Thailand
- 22. Kennesaw State University**
Marietta, Georgia, USA
- 23. Kyushu Institute of Technology**
Kitakyushu City, Fukuoka, Japan
- 24. McGill University**
Montreal, Quebec, Canada
- 25. Mukesh Patel School of Engineering**
Mumbai, Maharashtra, India
- 26. National Institute of Technology, Rourkela**
Rourkela, Odisha, India
- 27. National University of Singapore**
Singapore, Singapore
- 28. North Carolina State University**
Raleigh, North Carolina, USA
- 29. Northwestern Polytechnical University**
Xi'an, ShaanXi, China
- 30. Norwegian University of Science and Technology**
Trondheim, Norway
- 31. Prairie View A&M University**
Prairie View, Texas, USA
- 32. Project Radian**
Temecula, California, USA
- 33. Ryerson University**
Toronto, Ontario, Canada
- 34. San Diego City College**
San Diego, California, USA
- 35. San Diego Robotics 101**
San Diego, California, USA
- 36. San Diego State University**
San Diego, California, USA
- 37. Team Inspiration**
San Diego, California, USA
- 38. Texas A&M University**
College Station, Texas, USA
- 39. The Center for Robotics Development**
Vladivostok, Russia
- 40. The Ohio State University**
Columbus, Ohio, USA
- 41. Université du Québec à Trois-Rivières**
Trois-Rivières, Québec, Canada
- 42. University of Alberta**
Edmonton, Alberta, Canada
- 43. University of California, Berkeley**
Berkeley, California, USA
- 44. University of California, Riverside**
Riverside, California, USA
- 45. University of California, San Diego**
La Jolla, California, USA
- 46. University of Colorado at Boulder**
Boulder, Colorado, USA
- 47. University of Florida**
Gainesville, Florida, USA
- 48. University of Illinois - Urbana Champaign**
Champaign, Illinois, USA
- 49. University of Maryland**
College Park, Maryland, USA
- 50. University of Maryland, Baltimore County**
Baltimore, Maryland, USA
- 51. University of Missouri**
Columbia, Missouri, USA
- 52. University of Puerto Rico at Mayagüez**
Mayagüez, Puerto Rico
- 53. University of Southern California**
Los Angeles, California, USA
- 54. University of Victoria**
Victoria, British Columbia, Canada
- 55. Utah State University**
Logan, Utah, USA
- 56. Wroclaw University of Science and Technology**
Wroclaw, Poland

12 Essential Innovation Insights

For decades, researchers have published their findings about innovation in MIT Sloan Management Review. Here are a dozen of the best insights.

- Innovation isn't necessarily about new things; it's about new value.
- Challenge competitors by playing a different game.
- Focus on identifying and resolving uncertainties in innovation projects.
- Remember that being first to market is no guarantee of success.
- Let your customers develop your next product.
- Think of invention as a process of creating new combinations of elements — with results that have a highly skewed distribution.
- Understand your options for working with external innovators.
- Create systems and structures that support ongoing innovation.
- Connect the people in your organization who identify new ideas with those who can commercialize them.
- Innovation doesn't have to entail major breakthroughs; it can also involve making new product development faster and cheaper.
- Make customer communities your allies.
- Don't antagonize your creative people.