CHAPTER IV
GROUND AND SEA VEHICLES

A. INTRODUCTION

1. Definition and Scope

The Ground and Sea Vehicles technology area addresses platform and system technologies that support ground vehicles (land combat and tactical vehicles and amphibious vehicles with a ground combat role) and sea vehicles (surface ship combatants and submarines). For ground vehicles, this includes intravehicle digitization, propulsion and power, track and suspension, chassis and turret structures, vehicle subsystems, hydrodynamics, integrated survivability, fuels and lubricants, and integration technologies. For surface ship combatants and submarines, this includes structural systems, maneuvering and seakeeping, power and automation, and signature control. The subareas covered by this technology area are identified in Figure IV–1.

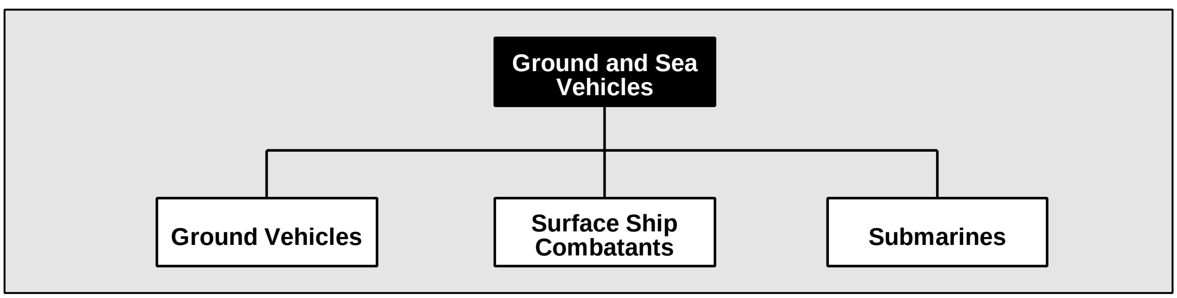

Figure IV–1. Planning Structure: Ground and Sea Vehicles Technology Area

2. Strategic Goals

The strategic goals for this technology area are driven by the warfighting needs described in Subsection 3 below and the realization that budget constraints will exist for the foreseeable future, thus impacting the acquisition and operation of all future military systems. Therefore, the primary strategic goal is to develop and demonstrate technologies for technological superiority of ground and sea vehicle systems over those of current and future adversaries, while significantly reducing the life-cycle cost. Budget constraints will also restrict the number of fielded systems, putting a premium on the ability of new systems to remain on station longer, whatever the threat. Therefore, an additional strategic goal is to provide options that will enable major improvements in survivability, sustainability, and reliability. With fewer new systems, another goal is to develop and demonstrate technology aimed at system upgrades. Ground vehicle technologies will provide future systems with greater deployability due to significantly reduced weight; more lethal combat systems through integration of advanced weapons; and more survivable scout, cavalry, and infantry systems through stealth, advanced armors, and hit avoidance techniques.

Sea vehicle technologies will provide options for increased stealth and survivability, increased reliability, and reduced life-cycle costs. Achieving these goals in the first decade of the 21st century will significantly contribute to the military effectiveness of future vehicle systems.

3. Acquisition/Warfighting Needs

The Ground and Sea Vehicles technology area supports the Force Projection/Dominant Maneuver and the Joint Readiness and Logistics and Sustainment of Strategic Systems Joint Warfighting Capability Objectives (JWCOs). The former JWCO includes the capability for fast deployment and maneuver of joint forces to rapidly dominate across the full range of military operations (amphibious, airborne, air assault, special operations, sustained land combat, operations other than war, etc.) with minimum casualties and minimum use of lift resources. The latter JWCO includes capabilities for enhanced simulation for training, improved and affordable operations and maintenance and life-cycle costs, mobility and sustainability, and upgrading existing strategic systems. Key planned products and transition opportunities are shown in Table IV–1.

Land combat vehicles, integrated with the combined arms force, are a central component of such initiatives as *Army Vision 2010* and Army After Next. Fielding of a rapidly deployed strike force, an idea endorsed by the Defense Science Board, is a high Army priority. Amphibious assault vehicles are likewise key to littoral operations and a seamless transition from sea to ground maneuver, consistent with USMC doctrine in *Operational Maneuver From the Sea*. The Navy’s current doctrine, *Forward . . . From the Sea*, emphasizes the littoral region as the primary operational area of surface ship combatants and submarines and continues the more traditional role of protecting the sea lanes. In support of this doctrine, surface ship combatants and submarines play a critical role in the Navy’s joint mission support areas of strike, littoral warfare, strategic deterrence, surveillance, strategic sealift, forward presence, and readiness.

B. DEFENSE TECHNOLOGY OBJECTIVES

Ground Vehicles

GV.01 Future Scout and Cavalry System
GV.03 Ground Vehicle Electronic Systems
GV.04 Advanced Ground Vehicle Mobility Systems
GV.13 Integrated Hit/Kill Avoidance Optimization
GV.14 Reconnaissance, Surveillance, and Targeting Vehicle
GV.15 Tactical Mobile Robotics
GV.16 Combat Hybrid Power Systems

Surface Ship Combatants

GV.06 Surface Ship Integrated Topside Concepts
GV.07 Surface Ship Advanced Electrical Power System
GV.08 Surface Ship Automation

Submarines

GV.09 Submarine Advanced Machinery Support System
GV.11 Submarine Electric Drive System

Table IV–1. Anticipated Ground and Sea Vehicles Technology Transition Opportunities

Current Baseline	2000	2005	2010
GROUND VEHICLES SUBAREA			
Virtual Prototyping	Abrams, Bradley, Tactical Vehicles	FSCS, Tactical Vehicles, AAAV	FCVs, FIV
Improved Armor, Signature Suppression, Active Protect, Hit Avoidance, Laser Protection, and Fire Suppression	Abrams, Bradley, Tactical Vehicles	FSCS, RSTV, Crusader, AAAV	FCVs, FIV
Band Track, Semiactive Suspension, Advanced Propulsion, Electric Drive	Abrams, Bradley, Tactical Vehicles	FSCS	FCVs, FIV
Lightweight Materials, Composite Structures		FSCS, RSTV, Crusader, AAAV	FCVs, FIV
Hybrid Electric Power, Advanced Crew-station Technology	Abrams, Bradley, Tactical Vehicles	FSCS, AAAV	FCVs, FIV
SURFACE SHIP COMBATANTS SUBAREA			
Integrated Topside Systems	LPD17	DD–21,CVN–77	CVX
Combat-Tolerant Advanced Double Hull Systems		DD–21	CVX, Far-Term Fast Sealift
Automated Damage Control Systems		DD–21	CVX
Advanced Degaussing System	MCM1, MHC51, LPD17	DD–21	CVX
Uninterruptible Electric Power		DD–21,CVN–77	CVX
SUBMARINES SUBAREA			
Machinery Truss Support System		NSSN Upgrades	Post-NSSN
Integrated Stern			Post-NSSN
Quiet Electric Drive		NSSN Upgrades	Post-NSSN
EM Signature Control	NSSN, SSN–21		Post-NSSN

C. TECHNOLOGY DESCRIPTIONS

1. Ground Vehicles

a. *Warfighter Needs*

The ground vehicle technology subarea addresses warfighter future operational capability (requirements per TRADOC Pamphlet 525–66, 1 December 1995. In the short term (1–2 years), the ground vehicle technology program concentrates on initiating a collaborative program between the United States and the United Kingdom for competing advanced technology demonstrations of the Future Scout and Cavalry System (FSCS)/Tactical Reconnaissance Armoured Combat Equipment Requirement (TRACER). It also features a substantial effort to develop technologies for an integrated combat vehicle survivability suite with active protection and advanced armor for lighter, more deployable combat vehicles. In the mid term, the technical and affordability goals of the FSCS Advanced Technology Demonstration (ATD) will be demonstrated, and the program will transition to engineering and manufacturing development. Efforts will continue to develop effective combat vehicle protection technologies with a goal of defeating large chemical energy and kinetic energy threats to medium-weight-class vehicles. The Army will support TRADOC's Army After Next initiatives by developing, modeling, and analyzing advanced combat vehicle concepts. Virtual prototyping will develop and demonstrate tools so that cost, schedule, and risk may be reduced 30% by exploring concept alternatives at program initiation. Far-term (6+ years) plans include furthering technology to include doubling cross-country ride performance for combat vehicles with Defense Advanced Research Projects Agency (DARPA) and Army active/semiactive suspension technology, electric drive, and semiautonomous unmanned vehicles. Far-term technologies will be integrated into a virtual system-level experimental platform to demonstrate increases in system effectiveness between 20% and 30%, while achieving reduction in system weight of up to 70% and a 50% increase in deployability as compared to the Abrams tank. Throughout the entire timeframe, commercial technologies will be sought that increase vehicle performance, safety, and reliability and that reduce the cost of ownership.

b. *Overview*

(1) Goals and Timeframes. The goals for the ground vehicles subarea are listed in Table IV–2.

Table IV–2. Ground Vehicles S&T Goals

Goal Area	2005
Reduce Vehicle Signatures (visual and thermal)	100%
Increase Threat Munition Defeat Capability	100%
Increase Crew Efficiency	100%
Increase Architecture Throughput	10X
Increase Propulsion Power Density	20–35%
Reduce Power Absorbed by Passengers/Crew	25%
Increase Structural Efficiency	70–80%

(2) Major Technical Challenges. There are numerous technical challenges for ground vehicles. By far, the most daunting challenge is protection of substantially lighter (e.g., ~20–25 tons), air-deployable combat vehicles against antiarmor threats designed to defeat heavy vehicles, like a main battle tank. The solution being pursued involves development of a combination of active protection (e.g., physical interaction of a countermeasure with a threat to destroy or degrade threat *before* it impacts the target) and ballistic armor. These countermeasures must be able to withstand attacks by such threats as rapid-fire, medium-caliber cannon; tank-fired, long-rod penetrators; antitank guided missiles with shaped charge warhead or explosively formed penetrators; and hand-held, high-explosive antitank munitions. The ground vehicle Integrated Hit/Kill Avoidance Optimization DTO (GV.13) addresses these challenges. Similarly, avoidance of being detected and acquired is important. Ground vehicles need affordable signature reduction technology that is robust in a dirty environment with high shock loading. Visual signature reduction concerns unique to ground vehicles must be addressed. Crewstation technologies that allow crew size reduction at a reduced crew workload must be accomplished; this is similar to accomplishments in aircraft. Driver automation techniques that improve mobility and increase utility of the vehicle driver must be integrated. Vehicle data rates and software lines of code approach those of fighter aircraft, but must be designed and maintained for current-generation crewstation and intravehicle electronics suite architecture. Training will be done in the motorpool with full crewstation compatibility with the Distributed Simulation Internet. Special-purpose standalone trainer simulators will no longer be needed. Mobility component weight and volume must be reduced while power is increased to support subsystem electrical loads. Critical to meeting all these technical challenges in an affordable and timely manner is the use of virtual prototyping (VP) and integrated product and process development (IPPD). VP and IPPD have been incorporated into ground vehicle ATDs requiring quality, affordability, and producibility to be among the primary development goals, in addition to the traditional technical performance.

(3) Related Federal and Private Sector Efforts. The TACOM National Automotive Center (NAC) and its industrial and academic partners are making partnership investments in innovative technologies that support the research, development, and manufacture of automotive products that have leveraged dual-use applications for Army and commercial systems. The mechanisms used are independent research and development (IR&D), dual-use application programs (DUAPs), Partnership for a New Generation of Vehicle (PNGV), and cooperative research and development agreements (CRDAs).

As IR&D resources are continually reduced, TACOM continues to maximize its technical and knowledge base through leveraging and influencing contractor IR&D priorities. In FY98, TACOM will leverage approximately $10 million through its primary and secondary defense contractors under the IR&D program. Contractors include, but are not limited to, General Dynamics/Teledyne Corporation, United Defense Limited Partnership, and General Motors Corporation/Allison.

TACOM’s current strategy to maximize these resources includes effective communication and outreach between TACOM’s technical staff and industry, automation of information resources via expanding use of Defense Technical Information Center’s CD–ROM IR&D listing and Internet facilities, and development of a database referencing TACOM tech base programs with applicable IR&D projects.

The FY98 DUAPs include hybrid-electric drive, 10 programs covering all aspects of diesel engine research, development of a virtual environment for ground vehicles, architecture for simulation-based acquisition (including a virtual distributed collaborative environment), and personal visualization hardware and software. The programs total $56 million in FY98.

The PNGV program is a collaboration between industry (GM, Ford, and Chrysler) and government agencies, including the Departments of Defense, Transportation, Energy, and Commerce.

CRDAs currently in effect cover a variety of technology thrust areas, including but not limited to high-performance computing processes and simulation-based acquisition, virtual design and development processes, synthetic human factors assessment, visual perception, alternative propulsion vehicle development, advancement of vehicle coverings and tarp technology, and other programs that advance the state of military ground vehicle technology while leveraging government and industry nonmonetary resources to promote dual-use and technology transfer to the commercial sector.

TACOM’s Visual Perception Laboratory supports dual-need automotive research programs in vehicle detectability by leveraging extensive capabilities in both industry and academia. An ongoing CRDA with General Motors uses this laboratory to measure the conspicuity of commercial and military vehicles on the nation's road system to increase visibility and reduce traffic accidents. The same facility operates to augment available field test data for the early test and evaluation of concept vehicle signature detectability. This facility is also a key element in calibrating and validating visual acquisition models to predict human performance in detecting ground vehicle camouflage and signature modification systems.

Other advanced automotive technologies are being transitioned through the TACOM NAC's initiatives and programs with DOE and industry. Smart vehicles are under development to demonstrate application of standard Society of Automotive Engineers data buses for vehicle infrastructure so that future electronic control and components can be easily added. NAC focuses on acquiring emerging automotive technologies not currently within DoD or the DoD contractor inventory for technology demonstrations and evaluation by the U.S. Army.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. ATDs and TDs are planned in all technical areas:

- Ground Propulsion and Mobility TD—demonstrate advanced mobility technologies in track, suspension, propulsion, and electric-drive technologies that will increase ride performance and platform stability of ground vehicle systems.
- Future Scout and Cavalry System ATD (DTO GV.01)—demonstrate all relevant chassis, sensor, survivability, communications, and mobility technologies that address scout-specific signature management, battlefield transportability, and platform stability issues in an electronically integrated system. This ATD can use the results of the DARPA hybrid and electric vehicle program applied to a scout mission. It addresses an Army requirement for a C–130 transportable scout vehicle. At least three designs representing different affordability goals will be carried forward until a three-star Joint Affordability In-Process Review is held approximately 12 to 18 months before the end of the ATD. This ATD cost is shared equally by the U.S. and U.K.
- Tactical Mobile Robotics—demonstrate critical levels of perception, autonomous navigation, and robust locomotion in urban and obstacle-intensive environments of man-portable robot teams for reconnaissance, communications relay, denied area operation, and specialized mission payload delivery.
- Reconnaissance, Surveillance, and Targeting Vehicle ATD (DTO GV.14)—demonstrate vehicle integration and mission payloads to fulfill USMC and USSOCOM missions that require internal transport via V–22 tilt-rotor aircraft. Propulsion, signature management, and suspension are key to developing the lightweight, narrow class of vehicles.
- Combat Hybrid Power Systems—demonstrate feasibility of lightweight future ground combat vehicles capable of improved mobility, survivability, and lethality through integration of electrical power components feeding continuous and pulsed power loads simultaneously. This program is co-sponsored by DARPA and Army.
- Future Combat Vehicle (FCV)/Future Infantry Vehicle (FIV) TDs—demonstrate, on virtual vehicle platforms, the mechanical and electronic integration of advanced crewstations integrated with open standard electronic architectures and embedded training, advanced distributed/area defense systems, next-generation tank propulsion systems, Land Warriors, selected leap-ahead lethality systems (i.e., electromagnetic/

electrothermal chemical, liquid propellant, missile, or conventional tank gun improvements), and other advanced combat vehicle technologies.

- Composite Armored Vehicle (CAV) ATD—demonstrated a 35% structural weight reduction (exceeding goal) in a modern, lightweight vehicle design through the full integration of structure, armor, and signature management while validating producibility, repairability, and affordability in parallel with performance-oriented goals. CAV technology was transitioned to Crusader, reducing its turret weight by 1 ton.

(2) Technology Development. The five ground vehicle technology development efforts include:

- System integration optimizes future system performance through establishing technology goals and objectives in conjunction with user-integrated concept teams and identifying future concept potential resulting from the new set of technological capabilities. Virtual prototyping and system-level integration laboratories are the primary ground vehicle system integration tools to simultaneously drive and establish technology goals and refine future system concept performance payoffs. Emerging vehicle requirements include up to 30 different mission applications.
- Chassis and turret structures investigates advanced materials applied to ground vehicle chassis and turret requirements of both new systems and system upgrades. The primary challenges are new lightweight structures and armor, signature treatments, producibility, and affordability.
- Integrated survivability provides the ground vehicle with an integrated set of survivability capabilities by achieving a balance of detection, hit, penetration, and damage avoidance technologies including laser protection and fire suppression. It includes signature treatments, electronic countermeasures (e.g., jamming, decoys), interceptors, obscurants, and advanced lightweight armors.
- Mobility focuses on tracked, wheeled, and amphibious ground vehicles. It includes track and suspension, engine (including electric power generation), transmission, propulsion unit (amphibious), fuels and lubricants, and various ancillary components (e.g., cooling and air-filtration systems).
- Intravehicle digitization develops and applies an open systems approach that integrates the vehicle digitization technologies with advanced crewstations that will enable current and future ground vehicles to effectively function and train on the real and virtual digital battlefield. Open architecture facilitates module commonality, system upgrades, and software reusability

(3) Basic Research. Critical research is being pursued in a number of ground vehicle programs. Significant work is being performed by Automotive Research Center (ARC), an innovative university–industry–government consortium leveraging commercial dual-use technology for the Army through ongoing and new programs in automotive research. The ARC is a key element of the basic research module of the TACOM’s NAC. Collocated with the U.S. big three automakers and their suppliers in the Detroit area, the ARC’s selected university partners include University of Michigan (lead university), Wayne State University, University of Iowa, University of Wisconsin, University of Alaska, University of Tennessee, and Clemson University. The

ARC provides extremely cost-effective support to the Army in areas of critical defense-focused automotive research. A primary thrust of the center includes development of complete computer simulations of defense-related vehicles. These simulations allow manufacturers to significantly reduce Army costs and design cycle time, along with the need for multiple Army hardware prototypes. Representative research areas of the center are vehicle terrain dynamics, vehicle hardware and human interface simulation, modeling and simulation of vehicle structures, advanced mobility simulation, and system integration. At this time, 35 industrial companies, including the domestic automakers, are actively participating in the research of the center.

The In-House Laboratory Independent Research (ILIR) program emphasizes state-of-the-art, in-house research that is absolutely essential if the Army is to maintain its worldwide technological leadership in the area of military ground vehicles. The program includes numerous leveraged collaborations between Army laboratory and university researchers that result in the greatly improved performance and cost effectiveness of Army systems, while allowing unique and high-technology results to be infused in the shortest possible time. The ILIR tasks of this program cover all generic areas of ground vehicle technology. Representative tasks include, but are not limited to, advanced propulsion technology, including ceramic engines without the need for cooling systems; unique vehicle signature analysis using acoustic and infrared wavelets; innovative ground vehicle simulation of active suspensions; and noninvasive thermal modeling of vehicle and engine characteristics.

Applied research is also being independently pursued in the areas of nonlinear vehicle dynamics and advanced propulsion systems. The work provides improved analytical tools to produce better performing components and systems in reduced time and cost. The work provides the scientific foundation for computer and laboratory-based modeling of the dynamics of tracked and wheeled vehicle performance to support modern warfare development, deployment, evaluation, and training. A principal thrust is real-time hardware and soldier-in-the-loop modeling of dynamics capability. The goal is to develop and demonstrate the theory and methodologies necessary to augment or eliminate expensive field and laboratory testing in many aspects of system design, acquisition, evaluation, and product improvement. The work also analytically examines advanced propulsion characteristics that offer significant potential in the areas of improved fuel economy, enhanced power density, reduced cost, and greater reliability.

2. Surface Ship Combatants

a. *Warfighter Needs*

Table IV–3 portrays improvements directly related to warfighter needs addressed by the surface ship combatants subarea. Correlation between the needs and goals defined in Section C2b(1) are also shown. The payoff quantification is based on a balanced combination of the payoff areas for the DDG–51 Flight IIA.

Table IV–3. Surface Ship Combatants S&T Impact on Warfighter Needs

Warfighter Needs	Payoffs (%)		Goal Area (Sec. C2b(1) below)		
	2000	2005	1	2	3
Reduce Probability of Mission Loss	50	85			✓
Reduce HM&E Acquisition Cost	15	30		✓	
Reduce HM&E O&S Cost	35	55		✓	
Increase Offensive Payload	50	100	✓		
Increase Mobility	20	30	✓		
Increase Sustainability	20	35	✓		
Increase Littoral Operating Envelope	20	25	✓		

b. *Overview*

(1) Goals and Timeframes. The following three goals represent potential improvements in hull, mechanical, and electrical (HM&E) subsystems for the indicated timeframes; the indicated improvements are relative to the notional Flight IIA upgrade to DDG–51-class destroyers:

(1) Increase Combat Effectiveness: 20% by 2000; 50% by 2005.
(2) Decrease Total Ship Ownership Cost: 20% by 2000; 35% by 2005.
(3) Increase survivability: 30% by 2000; 70% by 2005.

(2) Major Technical Challenges. The surface ship combatants S&T community is facing numerous technical challenges critical to the development of affordable ships that will meet future requirements such as operation in littoral regions. Principal challenges include reducing both topside weight and volume while reducing signatures and increasing sensor performance, minimizing weight and volume of HM&E systems while increasing combat tolerance and decreasing life-cycle costs, improving damage fight-through-and-recovery while minimizing manning levels and equipment redundancy, and providing automated intelligent monitoring and control systems for HM&E equipment.

(3) Related Federal and Private Sector Efforts. The surface ship combatants subarea leverages both private sector and other government investments. For instance, ship hardening efforts relate to the FAA Commercial Aircraft Hardening Program, the Foreign Ship and Submarine Vulnerability Program, and weapon development programs. Another example is that the power and automation area has an effort in power electronic building blocks (PEBBs) that is coordinated with DOE, DARPA, Army, and Air Force.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. Four ATDs are planned in the surface ship combatants subarea:

- *Advanced Degaussing*—significantly reduce surface ship underwater electromagnetic (EM) signatures in order to decrease vulnerability to underwater mines.

- *Low-Observable, Multifunction Stack*—demonstrate lightweight stack configuration with embedded communication antennas and having low radar cross section and infrared signatures.
- *Advanced Linear Motor*—demonstrate the viability of linear motor technology for aircraft recovery on the next-generation aircraft carrier.
- *Reduced Ships Crew by Virtual Presence*—demonstrate the feasibility of virtual watchstanding via a multifunctional, wireless sensor system that will provide real-time internal situational awareness.

(2) Technology Development. *Signature Control.* This technology area consists of three tasks: topside signature reduction, underwater signature reduction, and electromagnetic compatibility (EMC). The focus of the topside signature reduction effort is on developing methods to predict both radar cross section (RCS) and infrared (IR) signatures for complex ship topsides; developing concepts to fully integrate antennas, structures, and topside equipment into low-observable configurations; and reducing signature hull configurations. Underwater signature reduction addresses the development of acoustic silencing techniques for sea-connected piping systems and underwater hull appendages as well as methods to monitor and control real-time changes in magnetic signatures resulting from secondary magnetic fields. The EMC effort develops methods to predict the EM performance of topside antennas and concepts for embedding antennas into low-observable composite structures.

Power and Automation. This technology area comprises two tasks: mechanical power and auxiliary systems, and advanced electrical systems. Current and future efforts under the mechanical power and auxiliary systems task are directed at the development of improved power generation sources such as fuel-efficient gas turbine engines and diesel-fuel-fed fuel cells. The focus of the advanced electrical systems effort is on power distribution concepts that are highly survivable and provide uninterruptable electrical power, high-energy-density permanent magnet motors, and intelligent ship control systems.

Structural Systems. This technology area comprises four tasks: hull structures, topside structures, weapon effects, and damage control. The hull structures effort is focused on the development of new hull structural concepts, failure prediction methods, and probabilistic-based structural design methods. The focus of topside structures is on affordable, lightweight configurations that can be integrated with signature control measures antennas and combat protection schemes. The weapons effects area addresses methods to predict the effects of both above-water and below-water weapons on ship systems and affordable concepts that will protect ship systems from the effects of a variety of weapon threats. The damage control task focuses on the development of affordable and survivable sensors, automated damage control systems, alternatives to ozone-depleting fire suppression agents, and tactical decision aids.

Maneuvering and Seakeeping. This technology area has three tasks: seaway operability and survivability, advanced hull form concepts, and advanced propulsor concepts. The seaway operability and survivability task is focused on design criteria and tactical decision aids to maintain the dynamic stability of ships that have been damaged. The advanced hull form concepts task addresses efforts that are hydrodynamically efficient, have low-signature and good seakeeping characteristics, and are able to effectively accommodate advanced propulsor concepts. The advanced propulsor concepts task emphasizes propulsor technologies that are efficient, produce low signatures, and can be configured to be highly survivable compared to current conventional propulsors.

(3) Basic Research. The principal basic research efforts that directly support exploratory and advanced development efforts include micromechanics analysis for high-power, solid-state devices; artificial intelligence for fault-tolerant electric circuit breakers; and unsteady Reynolds-averaged Navier–Stokes for hydrodynamics.

3. Submarines

a. *Warfighter Needs*

The submarines subarea develops technologies to ensure U.S. submarine stealth superiority and to provide maximum performance at minimum cost. This subarea includes technologies traditionally associated with HM&E systems. Efforts are focused on submarine stealth, survivability, habitability, reliability, maneuvering, propulsion, affordability, automation, and payload capacity. These efforts provide essential technologies for submarines to support joint warfighting capabilities for decisive combat against regional forces, a range of capabilities for lower end operations, countering weapons of mass destruction, and near-perfect, real-time knowledge and communication. Table IV–4 portrays potential improvements in warfighter needs that can be achieved through efforts in this subarea. The baseline is the SSN–688.

Table IV–4. Submarine S&T Impact on Warfighter Needs (% improvement)

Warfighter Needs	2000	2005
Decrease Probability of Mission Loss	10	20
Reduce HM&E Acquisition Cost	5	20
Reduce HM&E O&S Cost	5	15
Increase Payload	10	25
Increase Sustainability	5	15
Expand Submerged Operating Envelope	10	25
Reduce Time to IOC	10	30

Transition opportunities include NSSN (next-generation nuclear attack submarine), post-NSSN, and Trident and SSN–688 backfits. Transitions require a high degree of performance verification given the severe operating environment, issues of crew safety and nuclear power, and platform cost.

b. *Overview*

(1) Goals and Timeframes. The overall goal is to provide technology options for covert, survivable platforms having improved joint warfighting capabilities. All goals are referenced with respect to the SSN–688 class with the exception of signature reduction goals, which are referenced with respect to the SSN–21 class. Due to security issues associated with submarine programs, quantification of goals and payoffs is often classified. Specific technology development goals are listed in Table IV–5. These goals represent the projection of impact that current and planned technology development could have on submarine platforms.

Table IV–5. Submarine S&T Goals (% improvement)

Goal	2000	2005
Reduce Design Cycle Cost and Time	10	20
Reduce Maintenance Cost and Time	10	20
Reduce Vulnerability to Weapons Effects	30	80
Reduce Signatures – Nonlittoral	40	80
Reduce Signatures – Littoral	40	80
Increase Submerged Operating Envelope	10	20

(2) Major Technical Challenges. The driving design requirements for submarines are control of acoustic signatures and shock resistance. These requirements influence all submarine systems and submarine costs. To achieve further reductions in acoustic signature and increases in shock resistance while reducing cost, new system-level approaches must be developed. An improved understanding of the physics of acoustics, underwater explosions, structural response, and hydrodynamics must be implemented in simulation-based design in order to evaluate these new approaches. Key challenges are (1) identification and reduction of force transmissions that result in radiated noise, (2) improved understanding of the hydrodynamic forcing mechanisms and the resulting response and acoustic radiation of structural components to these forces, (3) understanding of complex energy dissipating mechanisms for acoustic/shock isolation systems, and (4) capability to predict highly complex hydrodynamic flows to reduce the need for experimental evaluation and enable development of propulsors and maneuvering concepts. Nonacoustic signature technology is increasing in importance due to emphasis on littoral operations.

(3) Related Federal and Private Sector Efforts. The related federal and private sector efforts are limited due to the unique operating environment and the security issues associated with nuclear submarines. Research developments are monitored for potential relevance. Those efforts identified as relevant are coordinated through direct interaction and informal communication with the scientific community. Cooperation with foreign governments is limited by national security issues, although the United Kingdom has provided submarines for joint EM signature reduction efforts. Computational and fluid dynamics work is coupled with NASA and the aerospace industry when appropriate, and the power and automation area has an effort in PEBBs that is coordinated with DOE, DARPA, Army, and Air Force. The unique operating environment and requirements of submarines result in a limited community capable of addressing S&T issues.

c. *S&T Investment Strategy*

Submarine S&T investment strategy explores and develops technologies that provide design, construction, and operational options. Efforts are focused on ATDs and on technology developments supporting resolution of fleet deficiencies.

(1) Technology Demonstrations. No ATDs are currently planned in the submarine subarea.

(2) Technology Development. *Signature Control.* The objective is developing technologies that control acoustic and nonacoustic submarine signatures, within an acceptable cost, to ensure the stealth superiority of U.S. submarines against all threats. Acoustic signatures remain the most exploitable signature. Technology efforts are focused on fundamental areas of structural acoustics, hydroacoustics, EM signatures, and other nonacoustic signatures. Major sources of acoustic signatures are internal noise sources, transient noise from payload launch and other discharges, flow noise over the hull and appendages, propulsor-generated noise, and active sonar interrogation. Submarines are vulnerable to nonacoustic detection when operating in the littorals on or near the surface. Nonacoustic silencing must be compatible with acoustic silencing technology.

Structural Systems. The objectives are developing technologies that build structures providing balanced static and shock performance, providing shock and acoustic attenuating structures to support use of commercial-off-the-shelf equipment for cost reduction, supporting modular construction for cost reduction, and developing a computational live-fire capability to reduce the need for explosive shock testing.

Power and Automation. The objective includes reducing the weight, volume, energy, and maintenance impact of nonnuclear propulsion, machinery, and electrical systems. These systems support all aspects of operations—propulsion, electric power, combat systems, payload launch, sonar, and life support—while meeting acoustic, shock, and subsafe requirements. A key to achieving these objectives is the development of a reduced complexity, decentralized, electrically powered system. This approach supports and is compatible with the application of automation for reduced manning demand and damage recovery time. This effort also supports the development of electric-drive propulsion technology.

Maneuvering and Seakeeping. The objective is developing lower cost and improved performance propulsor concepts with improved maneuverability for littoral operations, fail-safe maneuvering systems, and simulation-based design capability to support new concept development and reductions in design cost. In addition to encompassing maneuvering and propulsion powering, this area is closely coupled with acoustic signature control. The dominant noise sources in the propulsor often require a demanding tradeoff between contradictory physical requirements of acoustic and hydrodynamic disciplines. This effort also supports the hydrodynamic design of advanced sail concepts.

(3) Basic Research. The basic research needs are improved physics-based understanding of structural acoustics, hydroacoustics, static and dynamic structural response, hydrodynamics, and electric system stability. With this understanding, new concepts can be developed that address the critical phenomena, and analysis tools can be constructed that enable both concept development and design tools for designers. In addition, materials that provide improved acoustic and nonacoustic performance and are compatible with deep submergence requirements are needed.