Office of Naval Research

Future Naval Capabilities Program:

Advanced Shipboard Desalination

BAA 11-010 " Demonstration System Development for Advanced Shipboard Desalination FNC"

Paul Armistead

Office of Naval Research

Industry Day

March 31, 2011, Long Beach, CA

ONR Future Naval Capability: Advanced Shipboard Desalination

Agenda

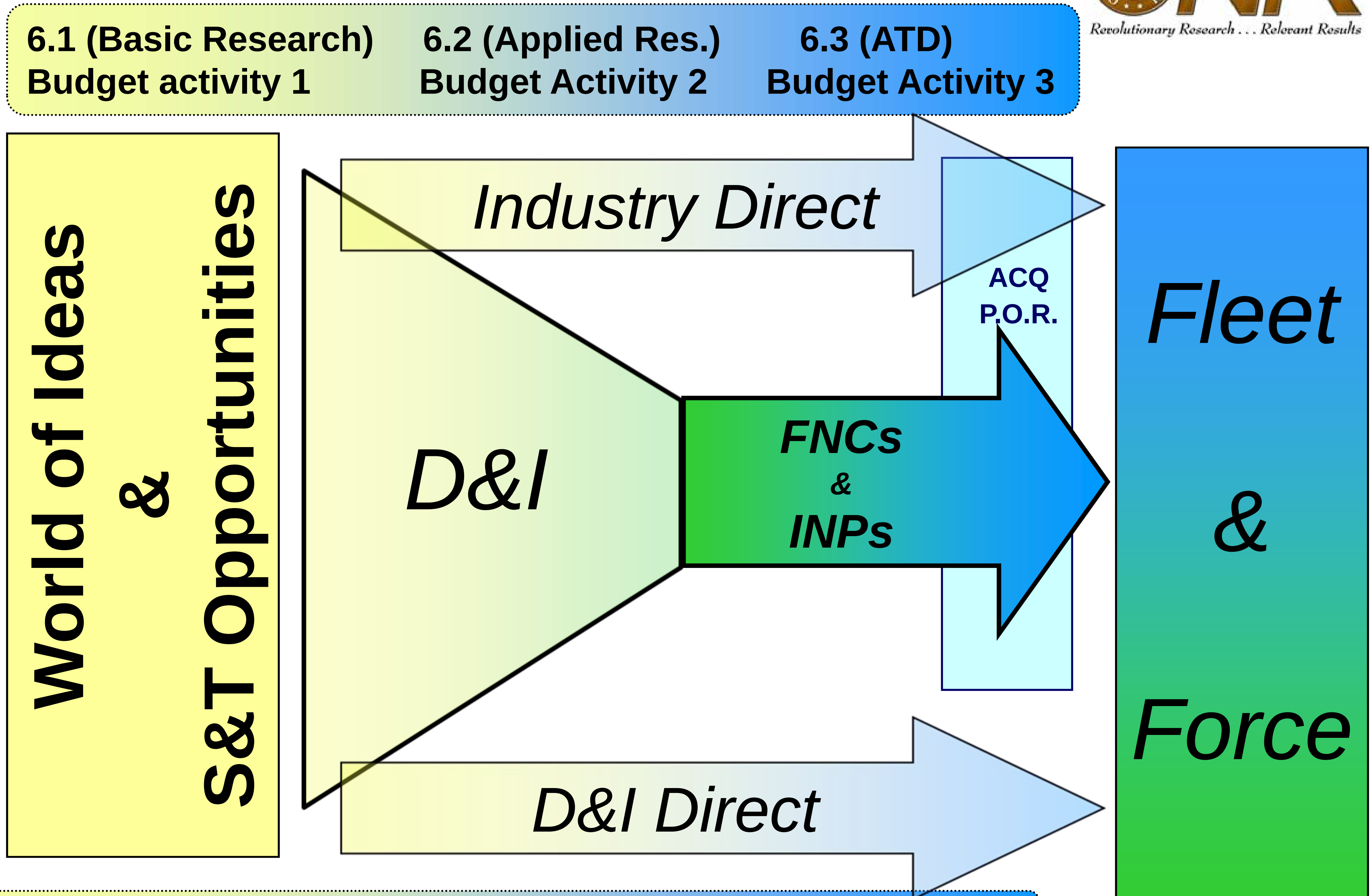
3:00 -	3:15	Opening Remarks	Paul Armistead Office of Naval Research
3:15 -	3:30	Current Navy Desalination Capability: Description, Strengths and Weaknesses	Ian Peek Navy NSWCCD
3:30 -	3:55	Improving Expeditionary Desalination Capability: First and Second Generation RO systems, EUWP Demonstrators	Mark Miller Army TARDEC
3:55 -	4:20	Performance Requirements for ONR FNC Shipboard Desalination Demonstrators	Dave Nordham Navy NSWCCD-SSES
4:20 -	4:40	break	
4:40 -	5:05	Design, Development, and Fabrication Stages of the FNC Program	Paul Armistead Office of Naval Research
5:05-	5:30	BAA Details, Dates, Procedures	Mike Evonic Office of Naval Research
5:30 -	5:40	Government Testing Capabilities for Evaluation of Delivered BAA Products	Bill Varnava Navy NFESC
5:40 -	6:00	Questions and Discussion	All speakers

Naval Research: Statutory Mission

<u>Office of Naval Research *(Public Law 588, 1946)*</u>:
"… plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security.… "

<u>Transitioning S&T *(Defense Authorization Act, 2001)*</u>:
"…manage the Navy's basic, applied, and advanced research to <u>foster transition</u> from science and technology to higher levels of research, development, test, and evaluation."

ONR S&T Product Flow



SBIR funding from tax on all funding

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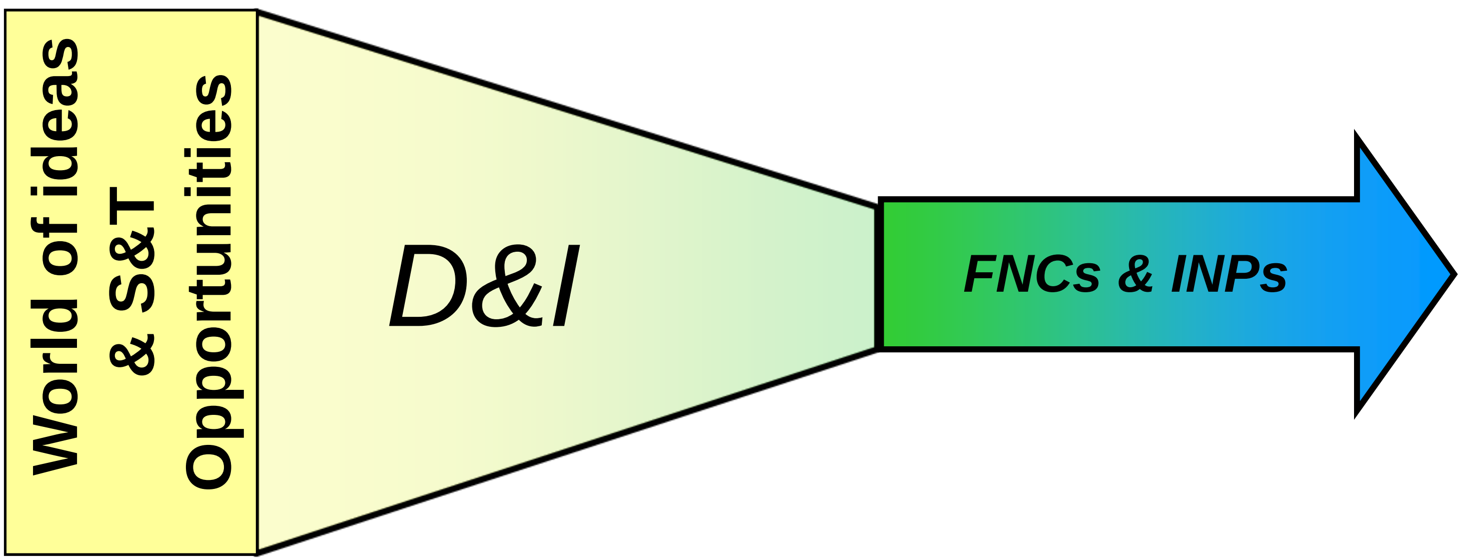
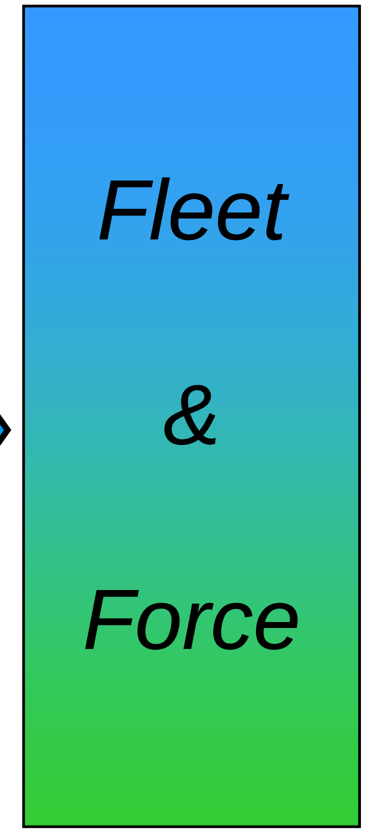
Revolutionary Research . . . Relevant Results

Future Naval Capabilities

- Operational Navy involved in decisions (needs pull)
- *Programs of record promise funds to test prototypes in service*
- Programs typically $3-6M per year for 5 years,
- TRL 3 to TRL 6





Innovative Naval Prototypes

- ONR hierarchy involved in decisions (technology push)
- If ONR builds it the operational services will come (Field of Dreams)
- Programs typically $3-6M per year for 5 years,
- TRL 3 to TRL 6

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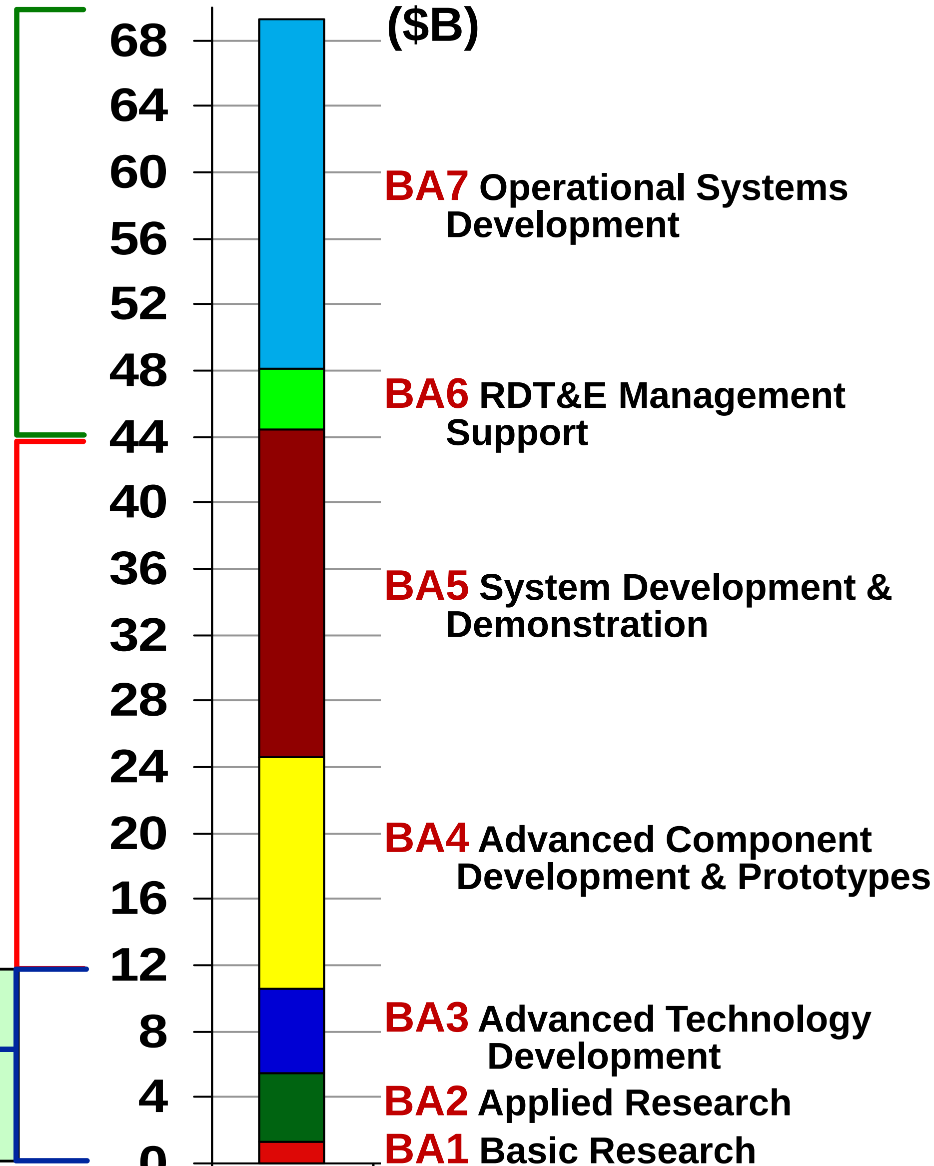
DoD FY06 RDT&E

FY06 RDT&E request = $69.36B
(Budget Activities 1-7)
DoD budget $405B



ONR FNC programs seek to transition technology to the fleet and require Technology Transition Agreements with increasing commitment from the fleet to fund the transition opportunity.

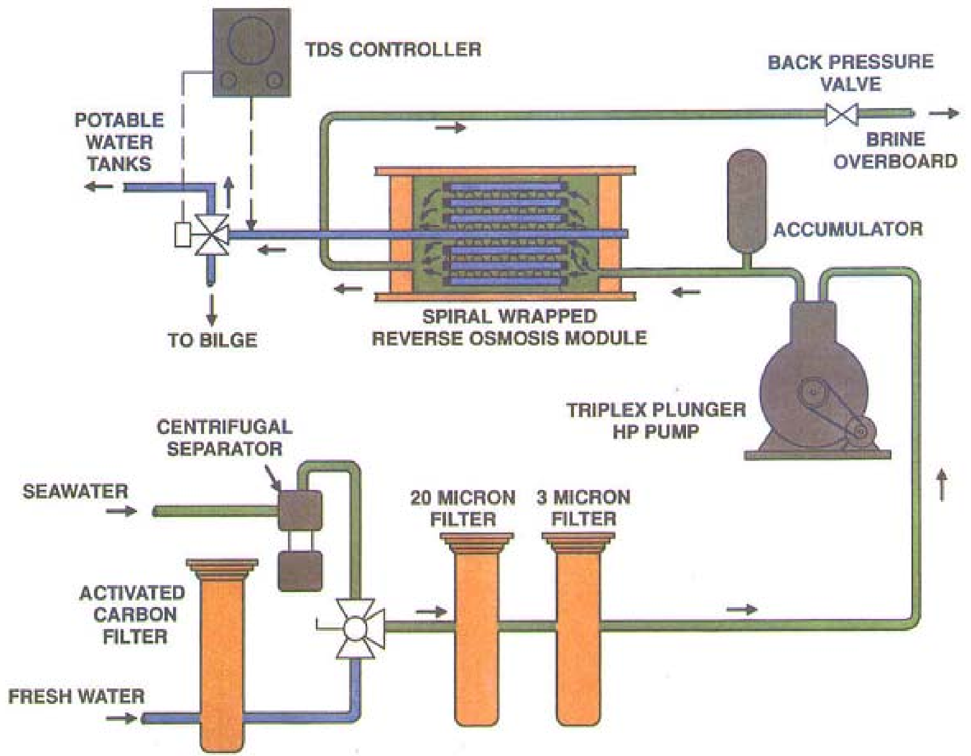
Science and Technology
(BA1 + BA2 + BA3 = $10.52B)
15% of RDT&E

Source:
FY2006_greenbook
OUSD comptroller

Revolutionary Research . . . Relevant Results

Enabling Technologies and S&T Issues

NSRO: Navy Standard Reverse Osmosis



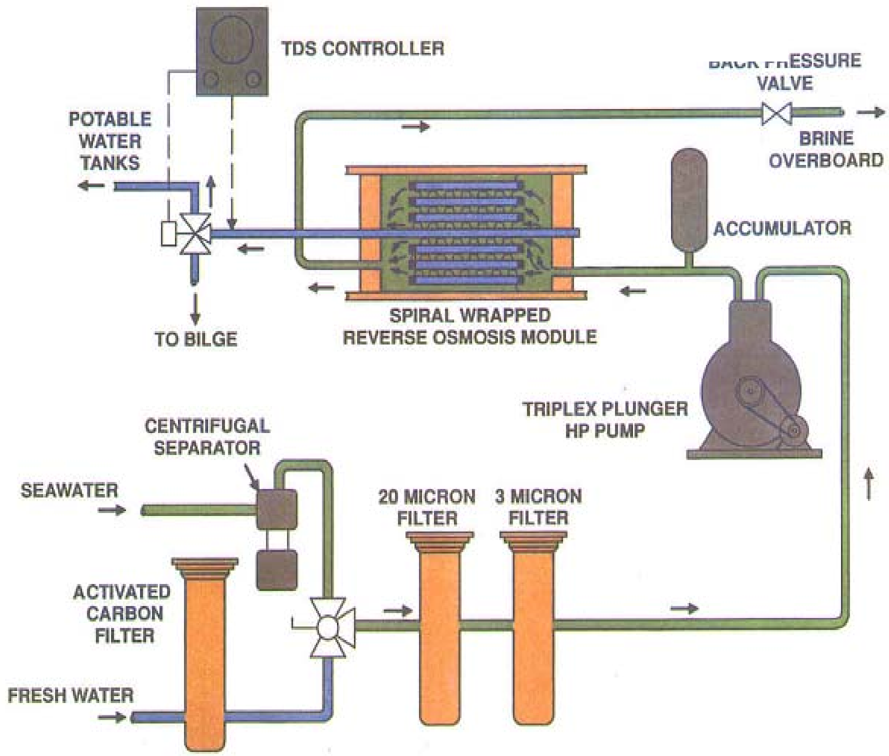
EC METRICS

- Develop an advanced shipboard desalination system that
  - costs the same or less than NSRO
  - occupies 40% less volume
  - has 40% less weight
  - uses 65% less energy
  - has 50% lower total ownership costs.
- The desalination system system will be able to operate in littoral environments at >95% operational availability, compared to as low as 50% operational availability in littorals with NSRO

Revolutionary Research . . . Relevant Results

Enabling Technologies and S&T Issues

NSRO:
Navy Standard Reverse Osmosis



EC Goal

- Develop and test several desalination demonstration units on more than one Navy ship class so that the benefits of next generation desalination are proven.
- Based on demonstrator performance, update Navy design guidance for all shipboard desalination systems (currently the guidelines for NSRO).
- Encourage adoption of new design approaches through backfit of old distillation or RO units or through new construction.

Revolutionary Research . . . Relevant Results

ONR Future Naval Capability: Advanced Shipboard Desalination

Timeline

Phase I: Component Development (mostly 6.2 or BA 2)

- MARCH 2009 ONR BAA 09-013 "Component Development for Advanced Shipboard Desalination Systems FNC"
- 01 FEB 2010 median award start date
- 01-AUG-2011 18 months, deliverables to Port Hueneme**
- 01-FEB-2012 2 years, final reports due**

Phase II: System Development (mostly 6.3 or BA 3)

- 10-MAR-2011 ONR BAA 11-010 "Demonstration System Development for Advanced Shipboard Desalination FNC"
- 02-MAY-2011 white papers 15-June-2011 full proposals
- 15-JULY-2011 award recommendations
- 01-JAN-2012 award begins
- 01-OCT-2014 available for ship installation

ONR Future Naval Capability: Advanced Shipboard Desalination

Timeline

Phase I: Component Development (mostly 6.2 or BA 2)

For the most part…

- Phase I awards are for component development that can be easily added or appropriate systems, i.e., improved RO membrane modules, improved pretreatment approaches
- Phase I deliverables and testing are from September 2011 through March 2012, after selection for phase II, and so encouraging developments in phase I may be implemented through the GFI or GFE approaches mentioned in the BAA
- We don't see further development opportunities at the component level in Phase II

Phase II: System Development (mostly 6.3 or BA 3)

- Whereas Phase I emphasis was raising technical maturity of promising components, Phase II must rapidly deliver systems capability of being tested in a real or simulated shipboard environment.

Phase I efforts: Desalination System

• Separation Systems:	Chlorine Resistant RO membranes
• NanoH2O:	High Flux RO membranes (nanoparticle)
• Ohio State Univ:	High Flux RO membranes (modified conventional chemistry)
• Teledyne:	Modified Spacers for low fouling RO modules
• Ocean Pacific:	Hydraulic axial piston recovery pump
• SRI International:	Hollow Fiber RO elements

Contracts awarded in March 2010 with anticipated evaluation of deliverables in Q4 FY11

Phase I Efforts: Pretreatment System

• HPD Membrane:	Ceramic Ultrafiltration membranes
• Porogen/Clean Membranes:	Low fouling, hollow fiber polymer UF membranes
• Advanced Hydro:	Low fouling coating for UF membranes
• UCLA (Cohen):	Process based control strategies
• PARC:	Spiral Channel membraneless prefiltration

Contracts awarded in March 2010 with anticipated evaluation of deliverables in Q4 FY11

Advanced Shipboard Desalination IPT

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Ian Peek	NSWCCD-Philadelphia
Jim Higgins	NSWCCD-Carderock
Bill Varnava	US Navy NFESC
Bob Shalewitz	US Army TARDEC
Jay Dusenbury	US Army TARDEC
Mark Miller	US Army TARDEC c/o NFESC
Michelle Chapman	US Bureau of Reclamation

Thank you

Current Navy Desalination Capability

Presented by:

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U.S. Office of Naval Research Industry Day
31 March 2011

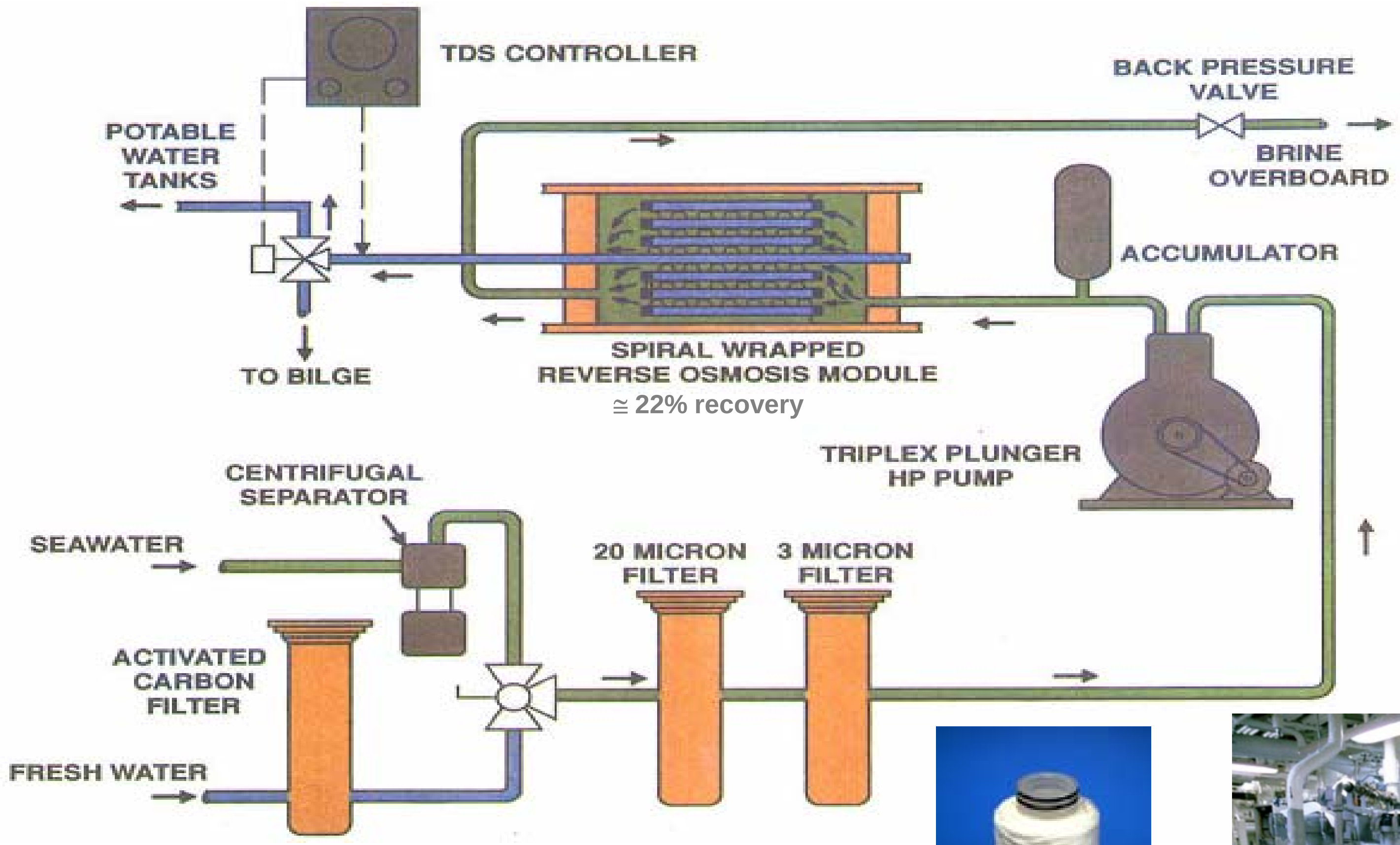
History Of Navy Shipboard Desalination

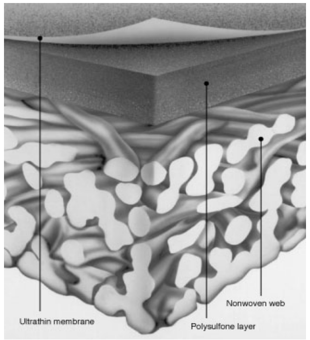
- Navy labs began investigating Reverse Osmosis (RO) membrane desalination in 1970's
  - ► Replacement for high maintenance, costly distilling units
  - ► First two (commercially developed) RO designs failed
  - ► Navy-designed prototype unit installed in 1988 on USS FLETCHER

  - – Successful OPEVAL and follow-on deployments
  - – Basis for the 12,000 gal/day Navy Standard RO (NSRO) unit now in wide service in the fleet

- NSRO technology is design basis for production of shipboard water on new ship designs.

Navy Standard Reverse Osmosis (NSRO) Plant





Revolutionary Research . . . Relevant Results

RO Desalination System Fleet Population

RO Plants Aboard US Navy Ships

Ship Class	RO Plant Capacity (gal/day)	Number In-Service/Planned
MCM 1	3,000	28
SSN/SSBN	4,000/6,000	110/50+
FFG 7 Class	6,800	62/--
DDG 51 Class	12,000	116/20
DDG 1000	12,000	0/6
JHSV	7,000	0/TBD
CG 47 Class	12,000	24/20
LCS	2,000	4/TBD
LHA 1 Class	12,000	12/0
LPD 17 Class	24,000	12/15
LHD 8	50,000	2/--
CVN 65	12,000	4/--
CVN 21 Class	125,000	--/4+

Over 2,500,000 hours of successful operation

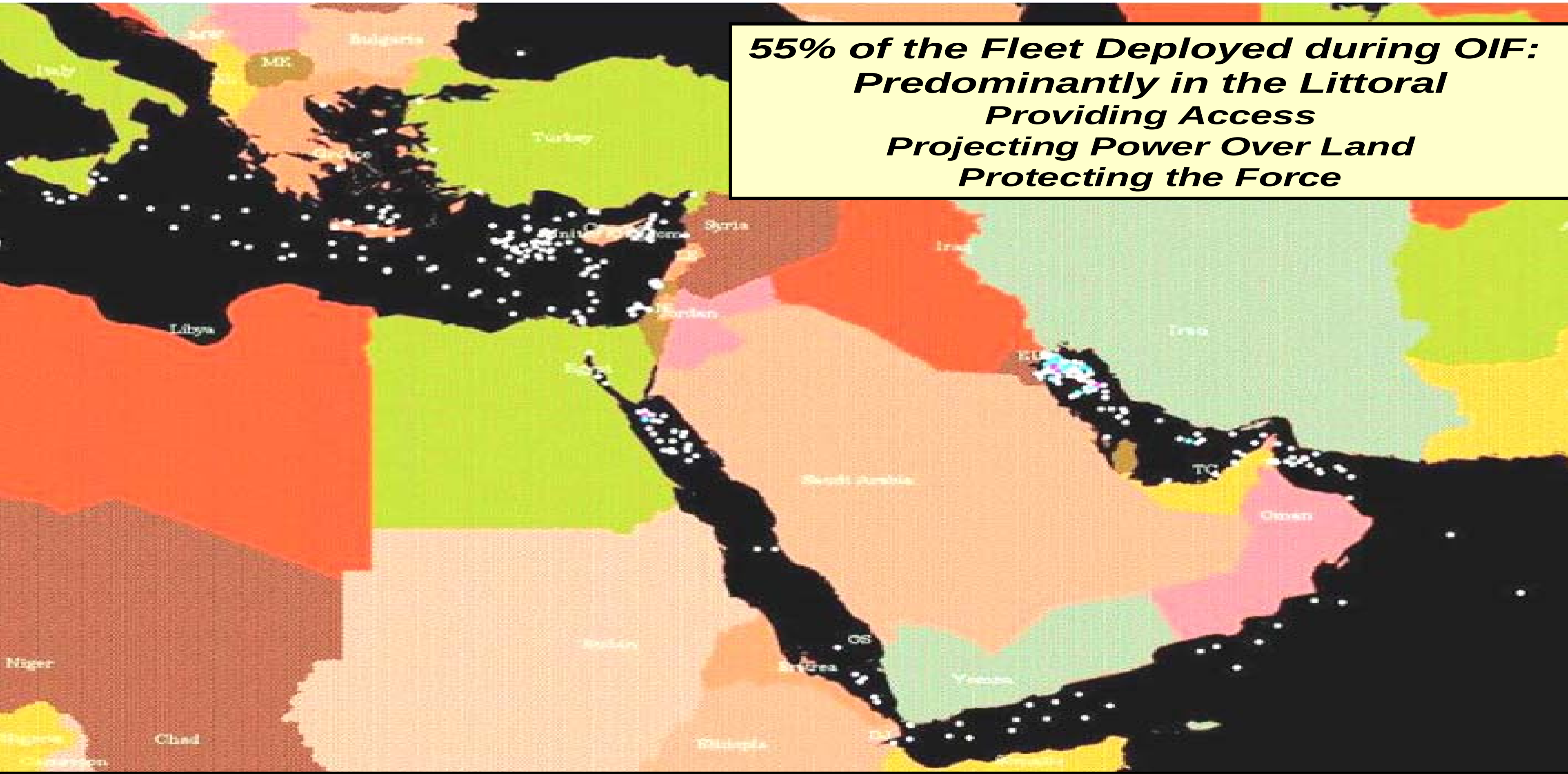
All new ship construction will use RO for desalination

RO Desalination Systems – Limitations and Issues

Pretreatment Issues

- NSRO designed for open ocean operations. Generally, long filter life and successful particle removal is being achieved in open ocean operations:
  - 4 to 6 weeks between cartridge filter replacements
    - 1 to 6 hours maintenance time
  - 3 to 5 years between RO element replacements
    - 4 to 12 hours maintenance time
- New naval strategic projections anticipate future operations likely to occur in littoral and coastal waters.
  - CNO SEA POWER 21 (Sea Shield, Sea Basing)
  - U.S. Maritime Forces A COOPERATIVE STRATEGY FOR 21ST CENTURY SEAPOWER

Revolutionary Research . . . Relevant Results



55% of the Fleet Deployed during OIF:
Predominantly in the Littoral
Providing Access
Projecting Power Over Land
Protecting the Force

Recent Maritime Operations Highlight the Need for Assured Access in the Littoral
We Must Operate Here, and Counter Asymmetric Access-Denial Threat

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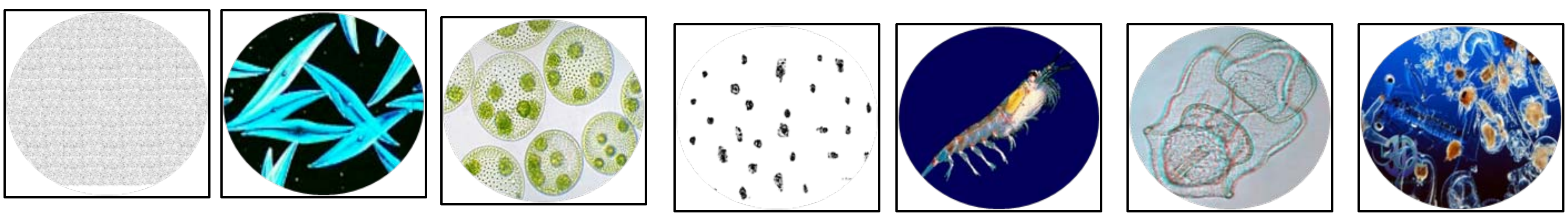
CAPT Ray Spicer, N76E Deputy for Surface Ships,
"Sea Shield: Assured Access in the Littoral", 23 October 2003

RO Desalination Systems – Limitations and Issues

Pretreatment Issues

- **More demanding particle filtration is required for shipboard RO systems operating in littoral/coastal zones where feed-waters contain:**
  - ► **Higher suspended particle levels than open ocean operations**
  - ► **A greater varieties of contaminates than open ocean operations, including:**



Silt	Bacteria	Algae	Sand	Krill	Star Fish Larva	Mixed Plankton
<1 - 50 µm	<1 - 5 µm	<1 - 10 µm	0.01 - 0.1 mm	1 - 2 mm	0.1 - 1 mm	0.1 - 2 mm

Micro-solids (neutrally buoyant or easily entrained) — Silt, Bacteria, Algae

Very dense and heavy — Sand

Macro-solids (neutrally buoyant) — Krill, Star Fish Larva, Mixed Plankton

Revolutionary Research . . . Relevant Results

RO Desalination Systems – Limitations and Issues

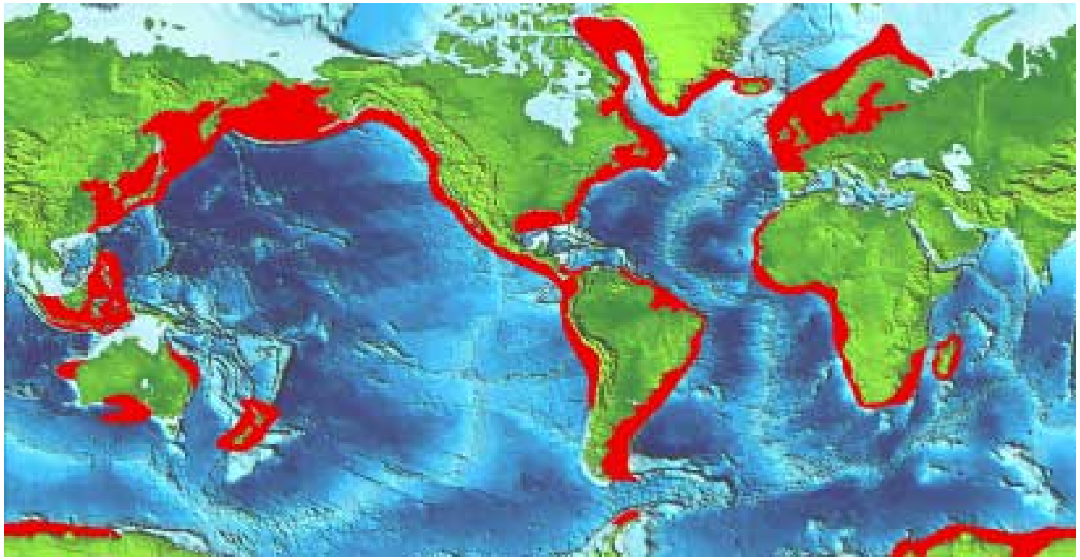
ALGAE CAUSING JUMP IN OCEAN "DEAD ZONES"

Scientists have found 200 "dead zones" in the world's oceans, a 34 percent jump from two years ago, a U.N. report yesterday showed.

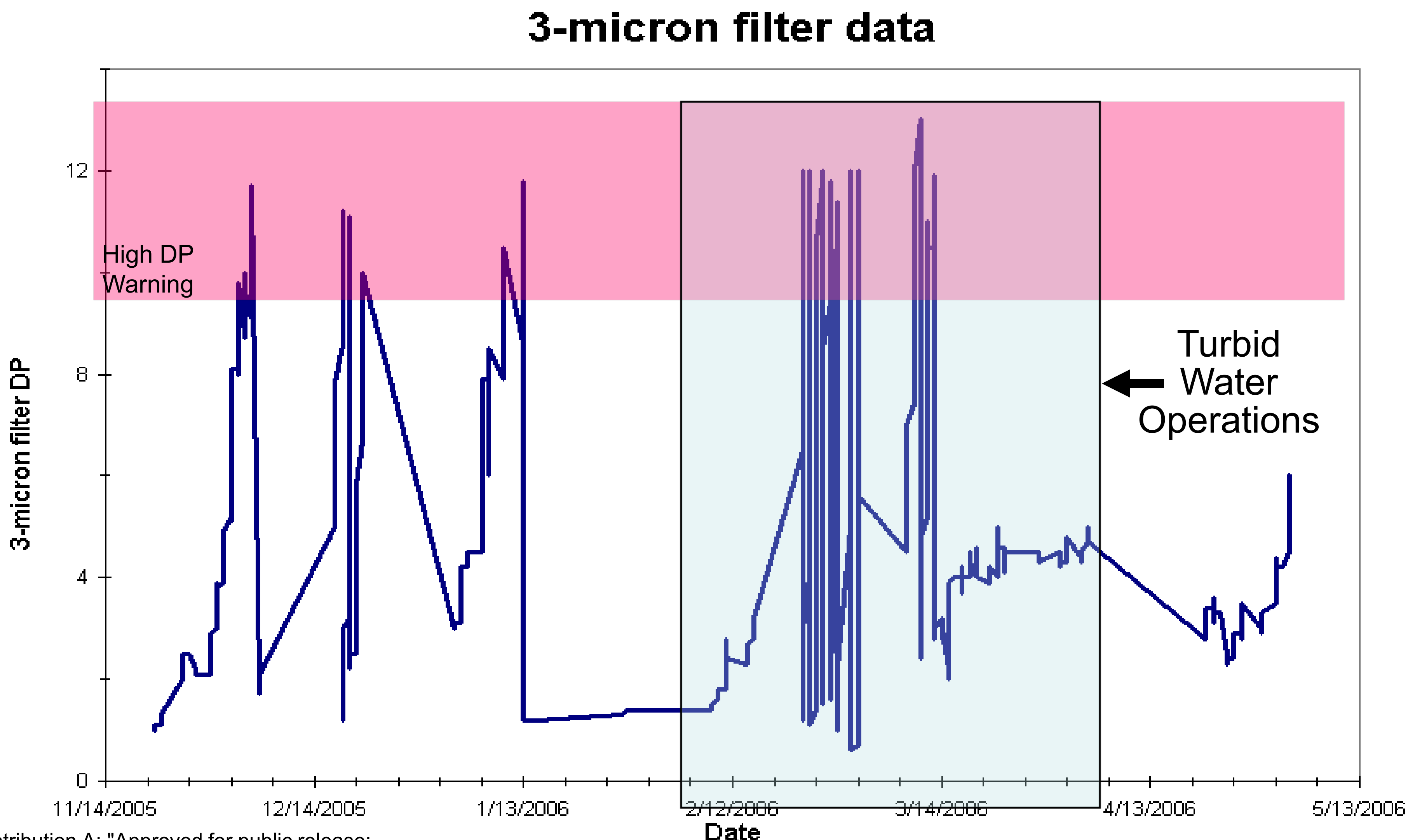
<u>Pollution-fed algae</u>, which deprives other living marine life of oxygen, are the cause of most of the dead zones, <u>areas often tens of thousands of square miles in size</u>. Scientists chiefly blame fertilizer and other farm runoff, sewage, and the burning of fossil fuels.

Those contain an excess of nutrients, particularly phosphorous and nitrogen, that cause explosive blooms of tiny plants known as phytoplankton. When they die, they sink to the bottom, where they are eaten by bacteria that use up the oxygen in the water.

Article in Washington Post 20 Oct 2006



RO Desalination Systems – Limitations and Issues



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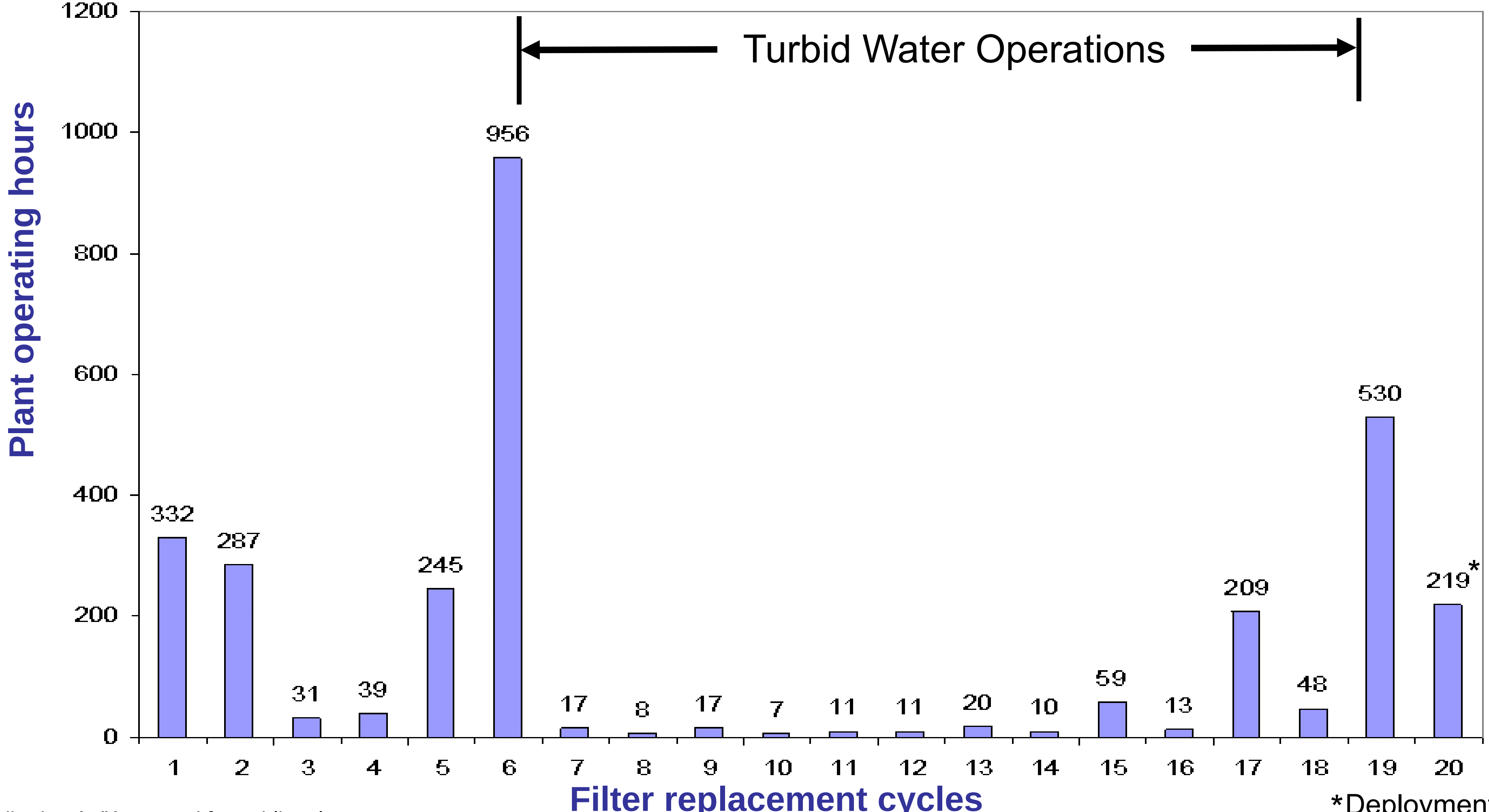
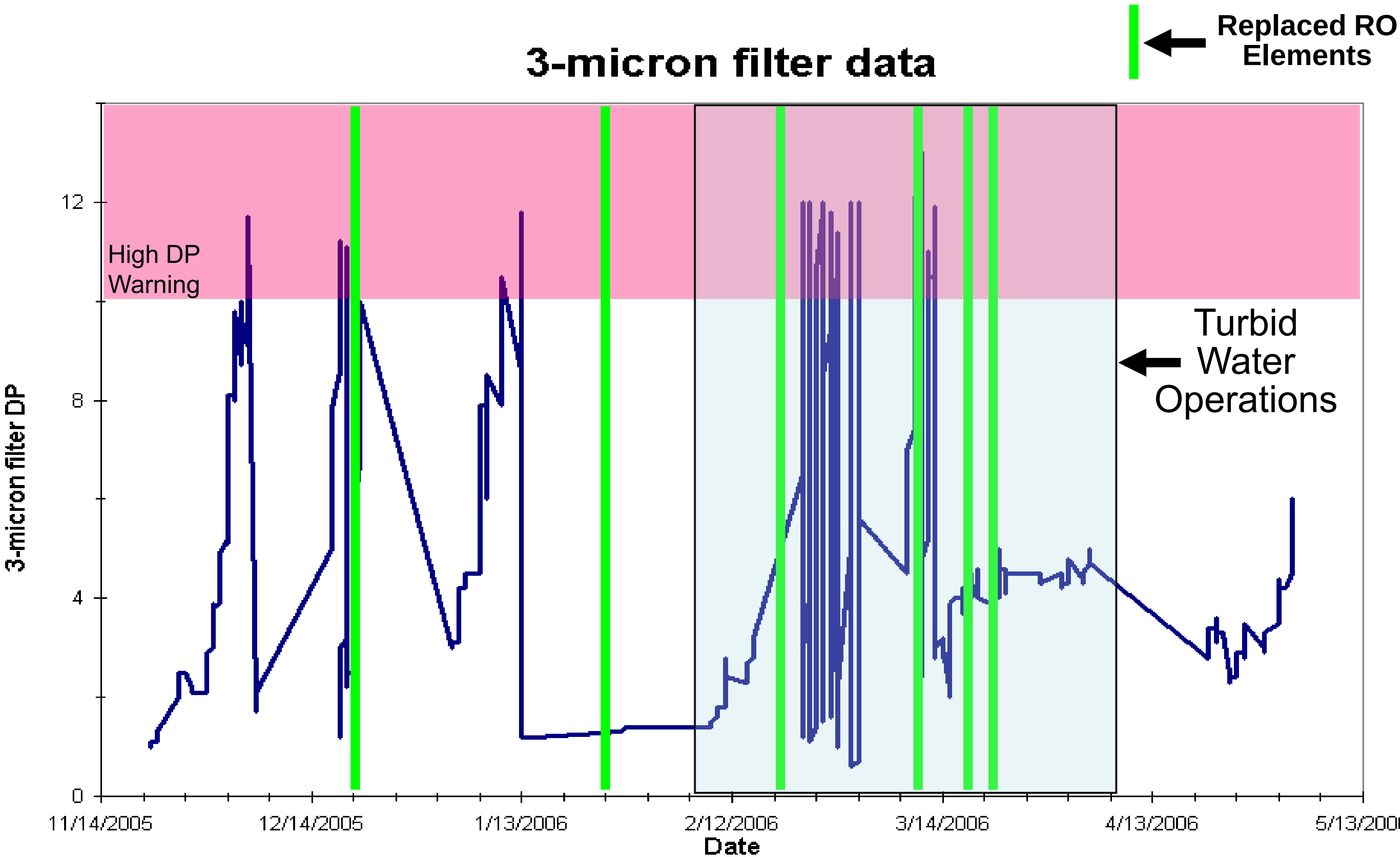
RO Desalination Systems – Limitations and Issues

Hours Between Cartridge Filter Replacements

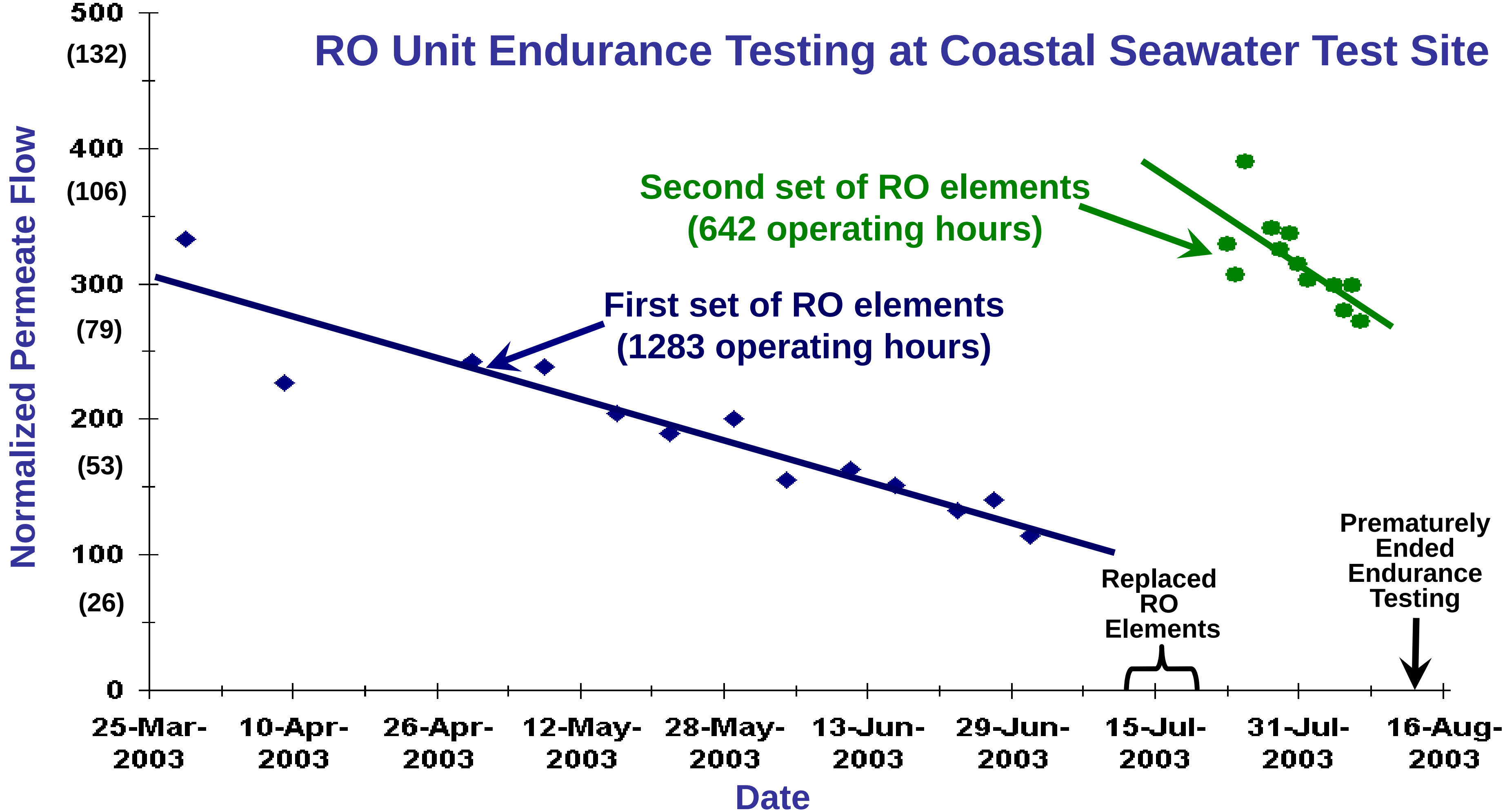


*Deployment ended

Shipboard RO Desalination Systems – Limitations and Issues



RO Desalination Systems – Limitations and Issues



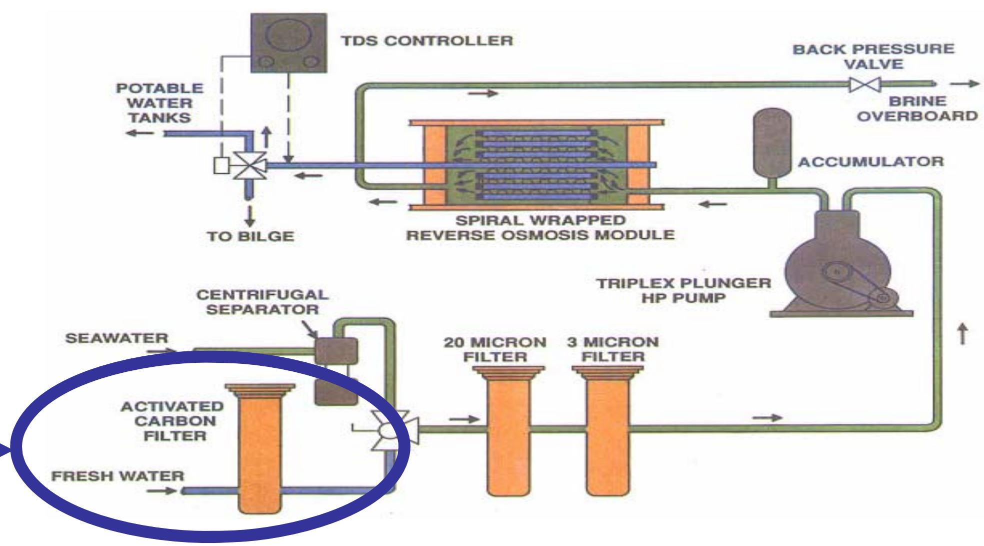
RO elements autopsy revealed accelerated fouling by primarily decaying organics and silt with particle size ranging between 0.1 and 1 µm

RO Desalination Systems – Limitations and Issues

Chlorination of seawater piping

- **Biofouling and microbiological induced corrosion (MIC) protection (i.e., chlorination) of seawater systems - includes piping systems used as feed to RO plants**
- **RO membranes degrade in chlorinated environment:**
  - ► **Isolate RO system during chlorination periods**
    - ⇒ **may be up to 4 hours per day**
  - ► **Have dedicated, non-chlorinated feed seawater piping**
    - ⇒ **additional sea chests, pumps, piping, fittings, bulkhead penetrations**

Potable water flush used during RO shutdown procedures. ACF required for dechlorination protection. Extra monitoring and maintenance required.



RO Desalination Systems – Limitations and Issues

Size and Weight Issues

- Desire to increase potable water production capacity (to as high as 50 gal/person/day)
  - Current designs are 30 gal/person/day or less
  - Improved “quality of life” for sailors (no “*water hours*”)

- However, traditional technologies used in current RO units do not adapt to larger capacity RO system designs with comparable space and weight characteristics of distillation units:

Comparison of equivalent 100,000 gal/day plants

	Distillation Unit	Reverse Osmosis Unit*
Volume ($ft.^3$)	1900	2625 or greater
Weight (lbs.)	62,500	100,000 or greater

* Extrapolated from existing RO units

Summary

- Reverse osmosis technology developed in 1980's to address operation, maintenance, and cost issues associated with distillation plants and to meet all-electric ship requirements. Designed for open ocean operational scenarios.
- Traditional NSRO technologies have limitations and issues for future shipboard RO systems, including:
  - ► CNO SEA POWER 21 and U.S. Maritime Forces A COOPERATIVE STRATEGY FOR 21ST CENTURY SEAPOWER initiatives project more naval operations in littoral and coastal seawaters. Known limitations and problems associated with current RO pretreatment in these waters.
  - ► Operational concerns with chlorinated seawater
  - ► Space and weight limitations for desired increased water production capacities
- Advancements to RO technologies essential to being able to meet future Navy strategic goals

Improving Expeditionary Desalination Capability: 1st & 2nd Generation RO Systems, EUWP Demonstrators

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U.S. Office of Naval Research Industry Day
March 31, 2011 Hyatt Regency, Long Beach, CA

Military Water Treatment System Development

- 1^{st} Generation Mobile Systems
  - 600 ROWPU – fielded 1981
  - 3k ROWPU – fielded 1989
- 2^{nd} Generation Mobile Systems
  - 1500 GPH Tactical Water Purification System (TWPS) fielded 2004
  - Light Weight Water Purifier (LWP) fielded 2005
- EUWP
  - EUWP1 – 100,000 GPD Mobile Demonstrator – 2003
  - EUWP2 – 300,000 GPD Shipboard Demonstrator – 2005

1^{st} Generation Mobile Systems

Background

- Drinking Water Related Health Problems in WWI lead to development of the Mobile Water Purification Unit
- The Mobile Water Purification Unit found to be only partially effective during WWII
- After WWII, multiple units developed for various types of source water
  - Seawater Distillation Unit
  - NBC Treatment Unit
  - Fresh Water Purifier (ERDLATOR)
- Use of multiple units led to logistics and training problems
- US Government funded research in Reverse Osmosis led to fielding of Reverse Osmosis Water Purification Units (ROWPUs) in the 1980's

1st Generation ROWPU Systems (Army)

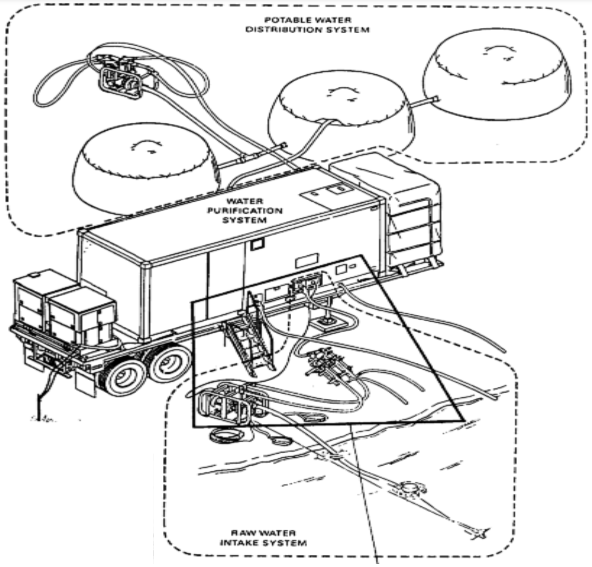
600 ROWPU

- Production
  - 600 gph (seawater)
  - 900 gph (fresh water)
- Multi-media filtration
  - Anthracite, sand, garnet
  - 6-7 gpm/sq. ft
- 5um cartridge filtration
  - 1 gpm / 10-inch equivalent
  - String wound, polypropylene
- Reverse osmosis
  - 8 ea – 6040 polyamide RO elements
  - Avg salt rejection = 99.4%
  - Series array
  - 50% rec. freshwater
  - 33% rec. seawater
- GAC, IX and chlorination post treatment for NBC removal

1st Generation ROWPU Systems (Army)

3k ROWPU

- Production
  - 2,000 gph (seawater)
  - 3,000 gph (freshwater)
- Dual-media filtration
  - Filter AG, garnet
  - 12-13 gpm/sq. ft
- 3um cartridge filtration
  - 2 gpm / 10-inch equivalent
  - String wound, polypropylene
- Reverse osmosis
  - 12 ea – 8040 polyamide RO elements
  - Avg salt rejection = 99.4%
  - 2x1x1 array
  - 50% recovery on freshwater
  - 33% recovery on seawater
- GAC, IX and chlorination post treatment for NBC removal

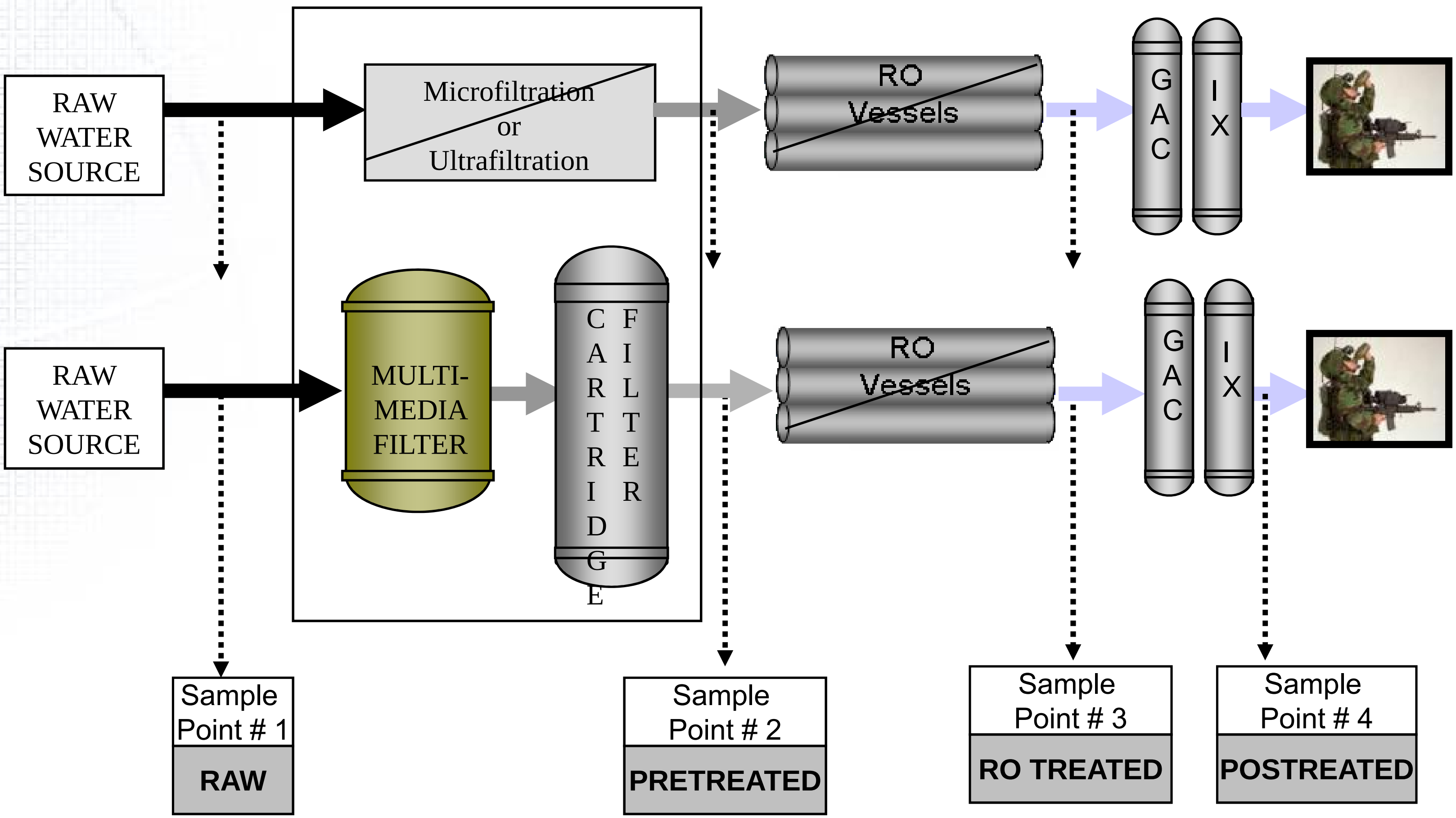


ROWPU Shortfalls

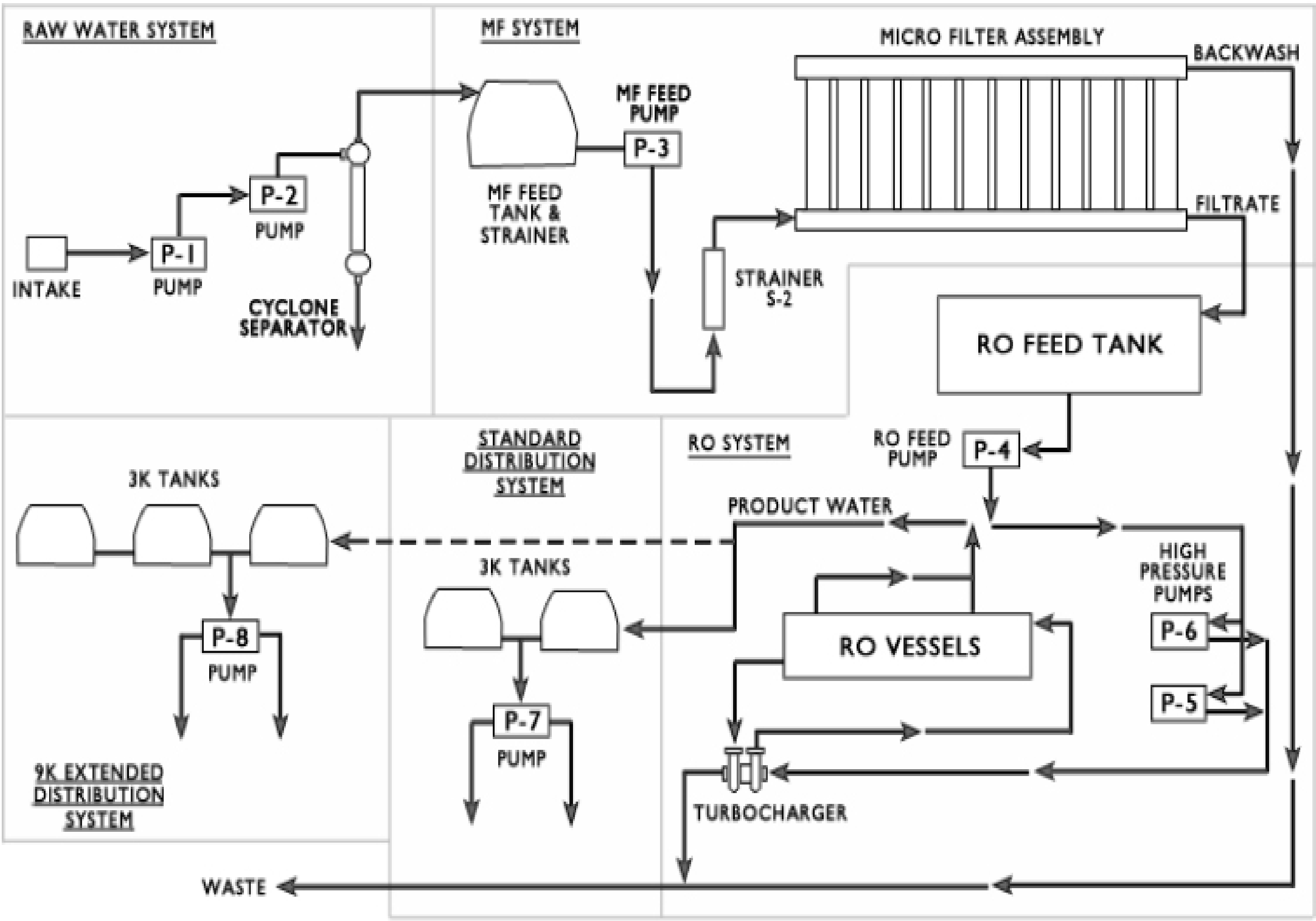
- Insufficient water production
- Outdated pretreatment technology (media filtration and cartridge filtration)
  - High cartridge filter and RO element replacement costs when operating on turbid source waters (greater than 20 NTU)
  - Increased time required for additional preventive maintenance checks and services (PMCS), filter backwash and filter replacement when operating on turbid waters
  - Operation on a very turbid water source (150 NTU) would be impractical due to the PMCS and logistical burden.
- Not capable of providing acceptable quantities of potable water from seawater with extremely high total dissolved solids (TDS) levels (< 35,000 ppm), such as those encountered during Operation Desert Shield and Desert Storm.
- Not capable of providing acceptable quantities of potable water from low temperature (e.g. 32 degrees Fahrenheit) water sources

2nd Generation Mobile Systems

Pretreatment System Upgrade



Integrated Membrane Systems



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Tactical Water Purification System (TWPS)

- Production
  - 1500 gph (fresh water)
  - 1200 gph (seawater) - *(28k gpd)*
- Strainer - 60 micron
- Microfiltration
  - MEMCOR system – 0.2 micron polypropylene hollow fibers
  - 12 MF modules/outside-in filtration
  - Backflushes every 15 mins for approx 1 min
  - Coagulant injection
- Reverse Osmosis
  - 10 ea – 8040 polyamide RO elements
  - Avg salt rejection – 99.7%
  - 50% recovery on freshwater
  - 36% recovery on seawater
  - Energy recovery - turbo
- GAC, IX and chlorination post treatment for NBC removal

Lightweight Water Purifier (LWP)

- Production
  - Freshwater – 125 GPH (3000 gpd)
  - Brackish/seawater – 75 GPH (1800 gpd)
- Ultrafiltration
  - Koch system – 0.05 micron polysulfone hollow fibers
  - 3 UF modules/inside-out filtration
  - Backflushes every 15 mins for approx 1 min
  - Coagulant injection
- Reverse Osmosis
  - 7 ea – 2540 polyamide RO elements
  - Avg salt rejection – 99.4%
  - 50% recovery on freshwater
  - 30% recovery on seawater
- GAC, IX and chlorination post treatment for NBC removal

Integrated Membrane System Implementation

Lessons Learned

- Able to operate on high TDS and low temp feeds
- Operate on feed waters with higher suspended solids
- Can run unattended for extended periods regardless of feed water
- Increased capacity over conventional system of similar size/weight
- Excellent feed water quality to RO resulting in extended element life

- High lifecycle cost
- MF replacement significantly more frequent then initially planned
- Single source of supply for pretreatment system components resulting in higher replacement costs
- Increased system complexity leading to maintainability issues
- Intermediate surge tank requires complex control
- Advantages of energy recovery must outweigh disadvantages

Expeditionary Unit Water Purifier (EUWP) Program

EUWP Technical Approach

- Development of demonstration plants using commercially available components that would highlight and exhibit current state of the art desalination technologies
  - ► Generation 1 (2003) – improvements to Army/Marine Corps mobile water purification systems. Special emphasis on system portability and reducing energy consumption.
  - ► Generation 2 (2005) – improvements to seawater desalination systems, with emphasis on limitations and issues related to Navy shipboard desalination. Greater water production capacity than Generation 1 for municipal water purification considerations

Gen 1 Expeditionary Unit Water Purifier (EUWP1)

Objective

- Develop a high-capacity, energy efficient, mobile water purification technology demonstrator capable of purifying a wide range of water sources with potential application towards, homeland defense, peacekeeping, humanitarian aid, and disaster relief.
- Maximum water production within C-130 transportability constraints (two 8x8x20-ft skids, ISO compatible)

Note: Values presented based on seawater feed	600 ROWPU	3000 ROWPU	A-TWPS	EUWP GEN 1
• Production Rate (gph)	600	2,018	1,200	4,170
• Avg RO Flux (gfd)	12	13.7	7.6	11
• MF/UF Flux (gfd)	na	na	25	40
• RO Recovery (%)	31	33	37	50
• Weight (gpd/lb.)	1.40	1.88	1.26	2.62
• Cube (gpd/cu.ft.)	31.3	28.8	22.5	38.9
• C-130 Lift (gpd)	43,200	48,500	28,800	100,000

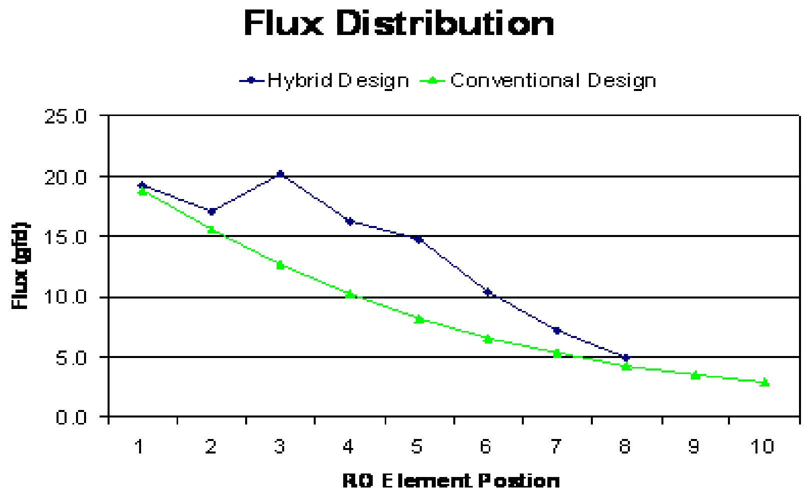
Gen 1 Expeditionary Unit Water Purifier (EUWP1)

Equipment Design Guidelines

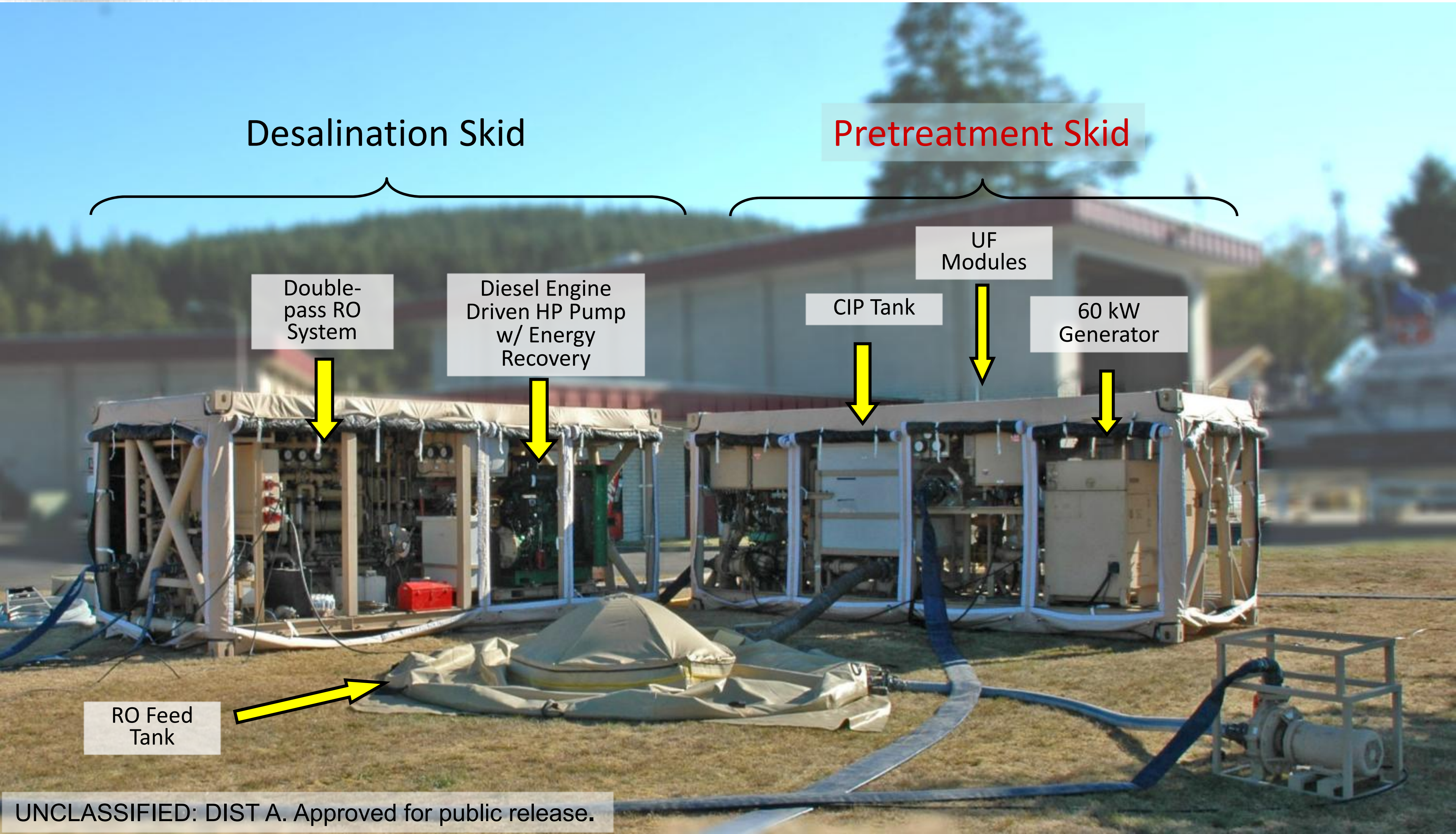
- Air transportable by C-130
- Produce 100,000 gpd product water meeting Tri-service standards (USA TBMED-577) on 45,000ppm, 77°F seawater feed
- Treat feed water to 60,000ppm TDS
- Feed water temperature range from 32°F to 95°F
- Feed water turbidity to 150 NTU
- Chemical agent removal
- 40,000 gallons of product water storage
- EMI/EMC
- Blowing rain/sand/dust

Gen 1 Expeditionary Unit Water Purifier (EUWP1)

- Production
  - Brackish/seawater – 120,000 gpd (single pass)
- Pretreatment
  - Backwashable strainer
  - UF System – 100,000 dalton cut-off polysulfone hollow fibers, inside-out filtration
  - 16 UF modules, 10"diam x 48" long, 544 ft^2 membrane area
  - Backflush @ 20 min intervals; duration approx 3 min
  - Coagulant injection
- Energy Recovery
  - Pressure Exchanger
  - Cascade Design (2:1 array)
  - Reduced size of HP pump
- Reverse osmosis
  - Internally staged array
    - 2 high rejection membranes
    - 2 low energy membranes
    - 4 extra low energy membranes
- Double Pass RO



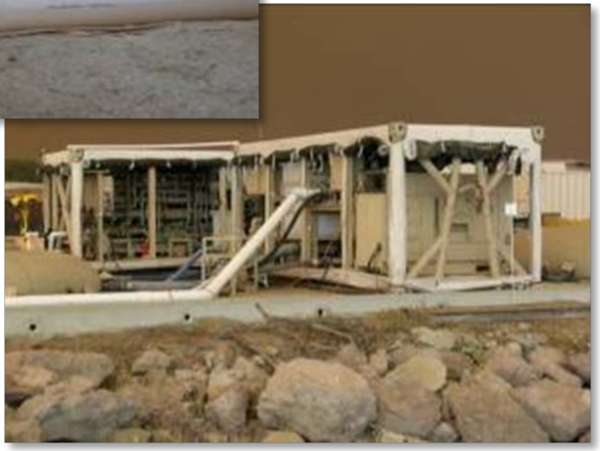
Gen 1 Expeditionary Unit Water Purifier (EUWP1)



Gen 1 Expeditionary Unit Water Purifier (EUWP1)

Testing & Demonstration

- Testing at SDTF, Port Hueneme, CA and BGNDRF, Alamogordo, NM
- Emergency Response:
  - USCG, Port Clarence, AK
  - Hurricane Katrina, Biloxi & Pascagoula, MS
  - Makah Nation, Neah Bay, WA
- EPA Environmental Technology Verification:
  - Microbial Removal, Gallup, NM
  - Surface Freshwater, Lake St. Clair, MI
  - Surface Seawater, Port Hueneme, CA



Gen 1 Expeditionary Unit Water Purifier (EUWP1)

Summary

- EUWP1 successfully demonstrated objective of exercise to develop high capacity, air-transportable water purification system.
- UF system required significant water storage off skid to account for backwash process
- Coagulant addition significantly extended operating time between CIP
- Energy recovery reduced power approx 30% and allowed reduction in high-pressure pump size
- Significant increases in water production per unit weight or volume are attainable.

however…

- UF and energy recovery results in relatively complex system that can be difficult to troubleshoot without proper training.
- Operator knowledge can significantly impact maintenance requirements
- System covers large area when operating

Gen 2 Expeditionary Unit Water Purifier (EUWP2)

Objective

Demonstrate existing State Of Art (SOA) desalination technologies and processes for improvements to seawater desalination systems, with emphasis on limitations and issues related to Navy shipboard desalination.

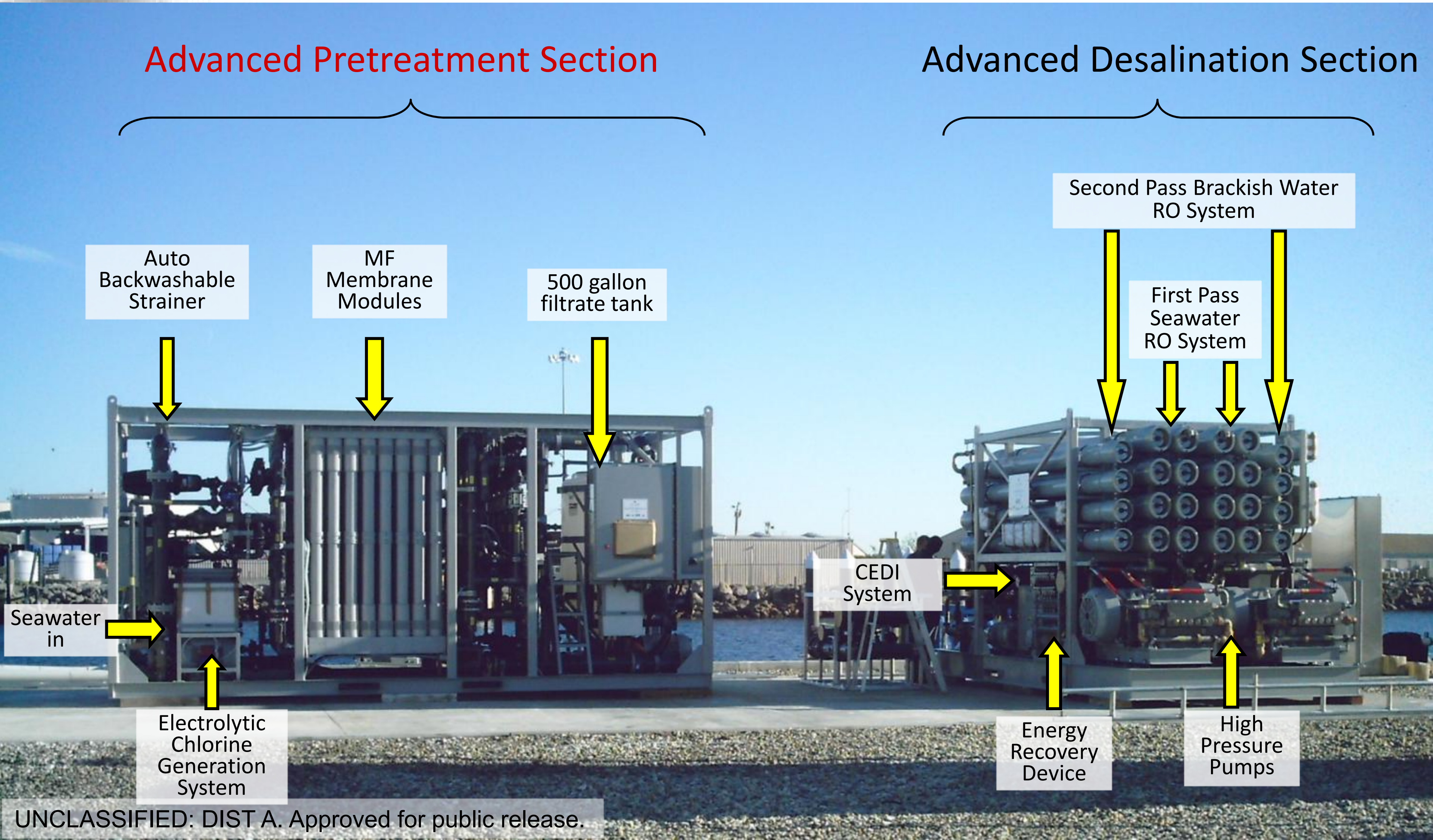
Goals

- Allow operation in near shore areas and longer deployments in locations of higher potential particulate fouling (e.g., Persian Gulf)
- Decrease energy requirements
- Improve reliability and maintenance requirements
- Increase desalination equipment availability
- Simplify operating procedures
- Increase water production capacity for "improved quality of life"

Gen 2 Expeditionary Unit Water Purifier (EUWP2)

- Production
  - Seawater – 300,000 gpd (double pass)
- Pretreatment
  - Backwashable strainer
  - MF System – 0.04 micron moninal pore size, pvdf hollow fibers, outside-in filtration
  - 5 banks of 16 UF modules, 410 ft^2 membrane area for each module
  - Backflush @ 28 min intervals; duration approx 7 min
  - 50ppm chlorine soak during bw, generated by electrolytic chlorine generator
  - Sodium bisulfite drip for dechlorination prior to RO
- Energy Recovery
  - Pressure Exchanger
  - HP pump(s) sized for 1^{st} pass product flow
- Reverse osmosis
  - Two parallel systems
  - Internally staged array
    - 2 high rejection membranes
    - 2 low energy membranes
    - 4 extra low energy membranes
- Second Pass RO
  - Tap water membranes
- Continuous electro-deionization *(third pass)*

Gen 2 Expeditionary Unit Water Purifier (EUWP2)



Gen 2 Expeditionary Unit Water Purifier (EUWP2)

Testing & Demonstration

- Completed testing at SDTF, Port Hueneme, CA:
  - 2,500 hours of successful operation of MF system without CIP
  - Over 2,000 hours of successful operating on RO system

Gen 2 Expeditionary Unit Water Purifier (EUWP2)

Summary

- EUWP2 successfully demonstrated that high capacity water purification systems utilizing few, if any, chemicals can be attained
- Chemically enhanced MF rinses or backwashes can significantly increase OP time between CIP
- Increased energy efficiency over 50% are attainable.
- Significant increases in water production per unit weight or volume are attainable.

However…

- Chlorine or other oxidants used to treat pretreatment system will damage RO if not removed
- Energy recovery devices can potentially complicate operating procedures.
- System was complicated and not user friendly
- Operator knowledge can significantly impact maintenance requirements

References

- D. Nordham, B. Varnava, M. Miller, J. Heinzel, I. Peek; **Coastal Seawater Testing of an Advanced Microfiltration/Reverse Osmosis Desalination Demonstrator;** ASNE Day 2009, National Harbor, MD, 8-9 April 2009.

- D. Nordham, B. Varnava, T. Hoffard, M. Miller; **Coastal Seawater Testing of a Full-Scale Microfiltration System for Shipboard Reverse Osmosis Pretreatment;** AMTA Annual Conference & Exposition, Austin, TX, 13-16 July 2009.

- D. Nordham, B. Varnava, M. Miller, T. Hoffard; **Coastal Seawater Testing of a Full-Scale MF System for Shipboard RO Pretreatment;** Ultrapure Water, Feb 2010.

Performance Requirements for ONR FNC Shipboard Desalination Demonstrators

Presented by:

NAVSEA
WARFARE CENTERS
Philadelphia

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Naval Surface Warfare Center Carderock Division
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U.S. Office of Naval Research Industry Day
March 31, 2011 Hyatt Regency, Long Beach, CA

ONR Advanced Desalination Future Naval Capability Program

- Based on success in EUWP Program, ONR selected advanced desalination for FY 2010 to FY 2014 Future Naval Capability (FNC) Program
- Advanced Desalination FNC Program goal: Push the development of desalination technology relevant to the constraints of operating on a Navy ship. Demonstrate this development through fabrication, shipboard installation, and at-sea operation of robust full-scale prototype plants
- Demonstration prototypes shall strive to meet Navy priorities:
  - Improved performance in all anticipated source waters (littoral, coastal, and open ocean)
  - Minimal manning requirements (e.g., operate unattended, be very reliable, and require little maintenance)
  - Compact size due to limited space on Navy ships
  - Little/no chemical usage or required chemicals generated in place
  - Low energy usage
  - Low total ownership costs (capital costs and operating and maintenance costs)

ONR Broad Agency Announcement 11-010

- To meet the Advanced Desalination FNC Program goal, ONR is interested in receiving proposals for the design, development, and fabrication of robust shipboard-ready desalination technology demonstration prototypes.
- In general, prototypes shall be capable of operating over a 6-month ship deployment and meet or surpass the following key performance requirements:
  - > 99% operational availability in open oceans
  - > 95% operational availability in littoral and coastal seawaters
  - > 50 gal/day per cubic foot volume
  - > 2 gal/day per pound weight
  - < 20 kW-hrs electrical energy consumption per 1,000 gallons produced
- To achieve these key performance requirements, pretreatment components should be capable of treating all feed water sources to recommended RO feed quality (SDI_{15} < 3.0, turbidity < 1.0 NTU). Desalination components should be capable of operating at > 35% recovery on feed seawater of:
  - up to 36,000 mg/L TDS and between 34°F to 105°F
  - up to 45,000 mg/L TDS and between 60°F to 105°F

ONR Broad Agency Announcement 11-010

- Shipboard desalination equipment should be designed to be able to:
  - withstand shock loadings (per criteria of MIL-S-901)
  - withstand environmental vibrations or internal excitation caused by unbalanced rotating components (per criteria of MIL-STD-167-1)
  - be electromagnetically compatible with surrounding equipment (per criteria of MIL-STD-461)
  - meet noise requirements (per criteria of MIL-STD-740)
  - be constructed of materials that will not create toxic fumes during fires in enclosed spaces or corrode from seawater service or in a salt atmosphere
  - operate on minimal or no hazardous materials and chemicals to reduce the storage, handling, and disposal issues of these items on Navy ships (per criteria of OPNAVINST 5090.1C)

White paper and full proposal submittals should include discussion and examples of competency and experience in providing equipment capable of meeting these requirements for military or shipboard systems.

ONR Broad Agency Announcement 11-010

- **Specific desalination systems of interest for this BAA are:**
  - **4,000 gal/day single-pass seawater RO desalination system**
    - capable of producing potable water (< 500 mg/L TDS)
    - single skid, maximum dimensions of 56 in. long x 56 in. wide x 64 in. high, maximum weight of 2,550 lbs. wet
    - electrical requirements shall not exceed 440VAC, 3-Phase, 60Hz, with a full load amp rating not to exceed 62 Amps
  - **18,000 gal/day single-pass seawater RO desalination system**
    - capable of producing potable water (< 500 mg/L TDS)
    - may be multiple skids, maximum total volume of 340 ft^3 (maximum height of 7 ft), maximum weight of 10,000 lbs. wet
    - electrical requirements shall not exceed 440VAC, 3-Phase, 60Hz, with a full load amp rating not to exceed 125 Amps
  - **100,000 gal/day high purity RO desalination system**
    - capable of producing 95,000 gal/day potable water (< 500 mg/L TDS) and 5,000 gal/day higher purity water (< 1.1 mg/L TDS)
    - skid-mounted, maximum total dimension of 22 ft long x 10 ft 8 in. wide x 9 ft 3 in. high, maximum weight of 52,000 lbs. wet
    - electrical requirements shall not exceed 440VAC, 3-Phase, 60Hz, with a full load amp rating not to exceed 250 Amps

ONR Broad Agency Announcement 11-010

- **Additional information for this BAA:**
  - **Phased design, development, fabrication and demonstration process**
    - **Phase I: Concept System Architecture Design (6 months)**
    - **Phase II (Option): TRL 5 Demonstration System (12 months)**
    - **Phase III (Option): TRL 6/7 Demonstration System (18 months)**
  - **Designs should incorporate an open-architecture approach to ensure that alternative components or government furnished equipment could be integrated as new technology is developed**
  - **Shipboard desalination systems include integrated controls, monitor, alarm, startup and shutdown functions that are centralized. Minimum instrumentation shall be as listed in Table I of BAA 11-010. Electronic data logging and diagnostics should be compatible with other shipboard systems and shall not be located in areas where they could be exposed to fluid leakage during calibration and maintenance.**
  - **Proposals under this BAA will only be accepted for complete systems. Proposals for individual component technologies <u>will not</u> be accepted. Each white paper and full proposal shall contain information for only one capacity demonstration system.**

Office of Naval Research

Future Naval Capabilities Program:

Advanced Shipboard Desalination

BAA 11-010 " Demonstration System Development for Advanced Shipboard Desalination FNC"

Paul Armistead

Office of Naval Research

Industry Day

March 31, 2011, Long Beach, CA

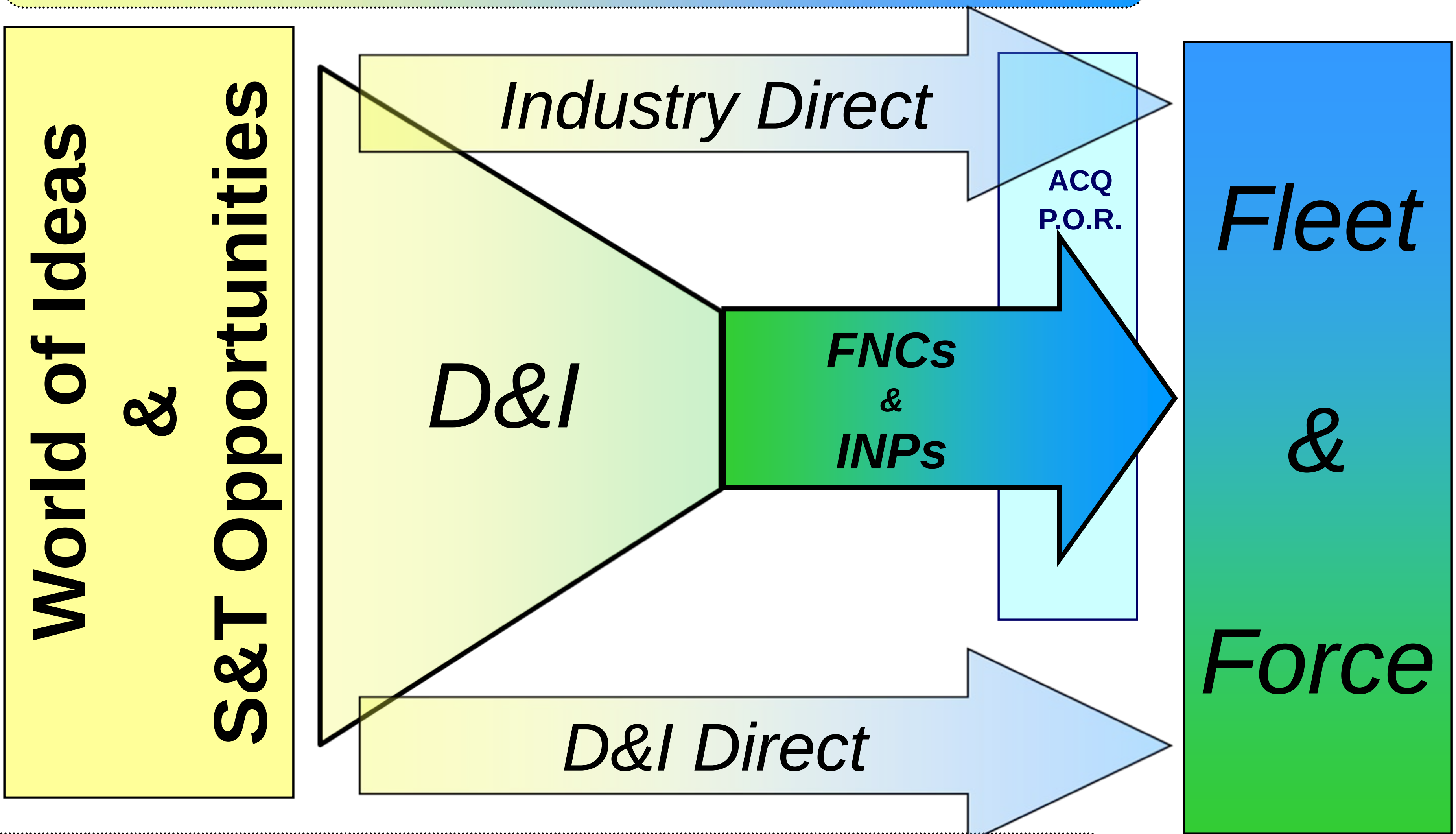
ONR S&T Product Flow

Revolutionary Research . . . Relevant Results

6.1 (Basic Research)
Budget activity 1

6.2 (Applied Res.)
Budget Activity 2

6.3 (ATD)
Budget Activity 3

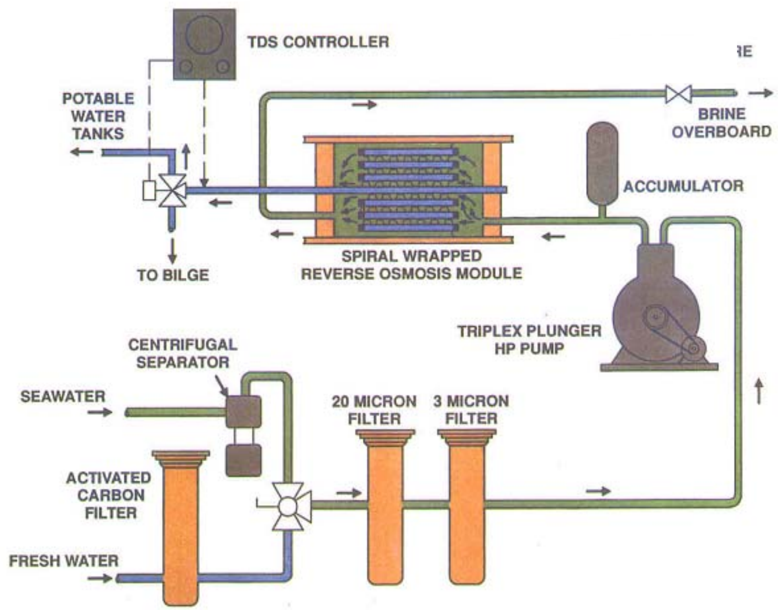


SBIR funding from tax on all funding

Distribution A: "Approved for public release; distribution is unlimited."

Enabling Technologies and S&T Issues

NSRO:
Navy Standard Reverse Osmosis



Desired Systems

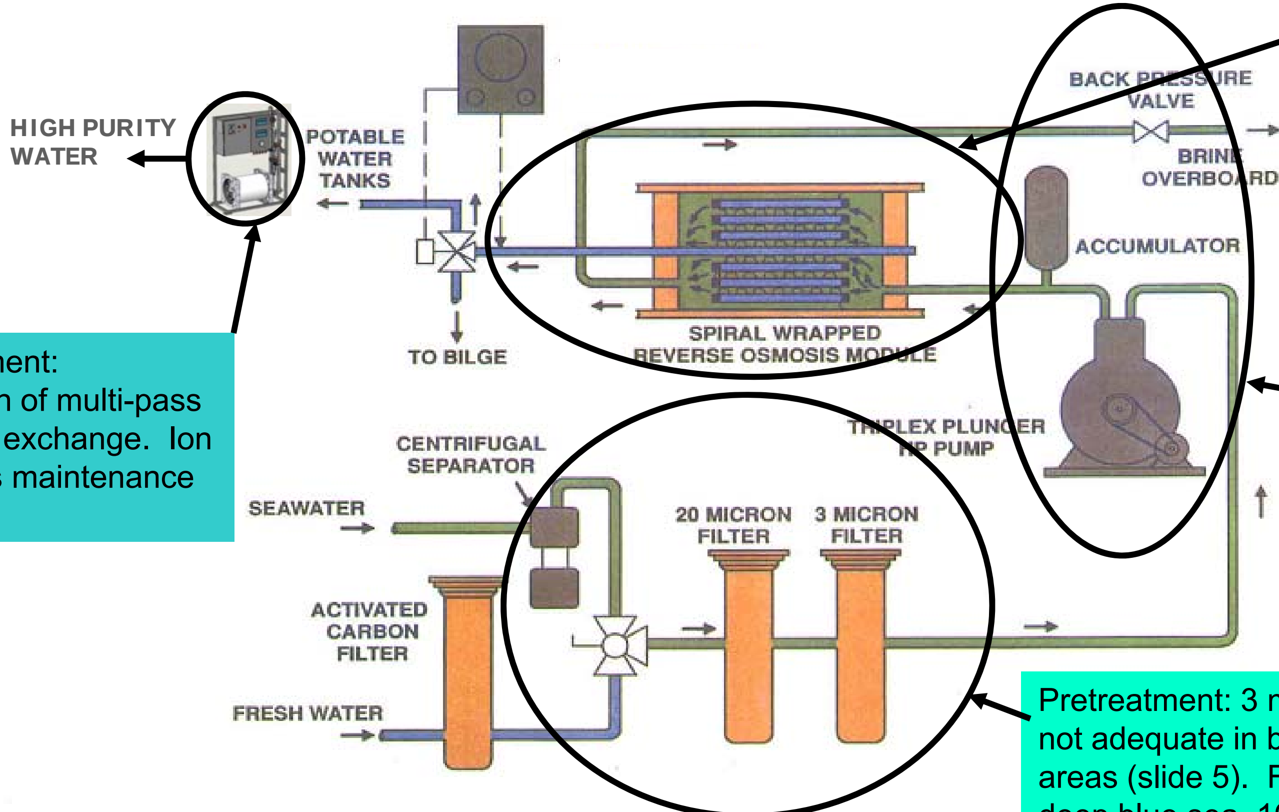
1. 4000 gallon per day single pass seawater RO
2. 18,000 gallon per day single pass seawater RO
3. 100,000 gallon per day mostly single pass RO

EC METRICS

- Develop an advanced shipboard desalination system that
  - costs the same or less than NSRO
  - occupies 40% less volume
  - has 40% less weight
  - uses 65% less energy
  - has 50% lower total ownership costs.
- The desalination system system will be able to operate in littoral environments at >95% operational availability, compared to as low as 50% operational availability in littorals with NSRO

Shortfalls in current capability

Desalination System Areas that need Improvement



Advanced Desalination: 20% recovery is for long membrane life, but results in pumping 100 gal to get 20 gal. Pumps and prefiltration must be oversized. Membranes are low flux and chlorine liable.

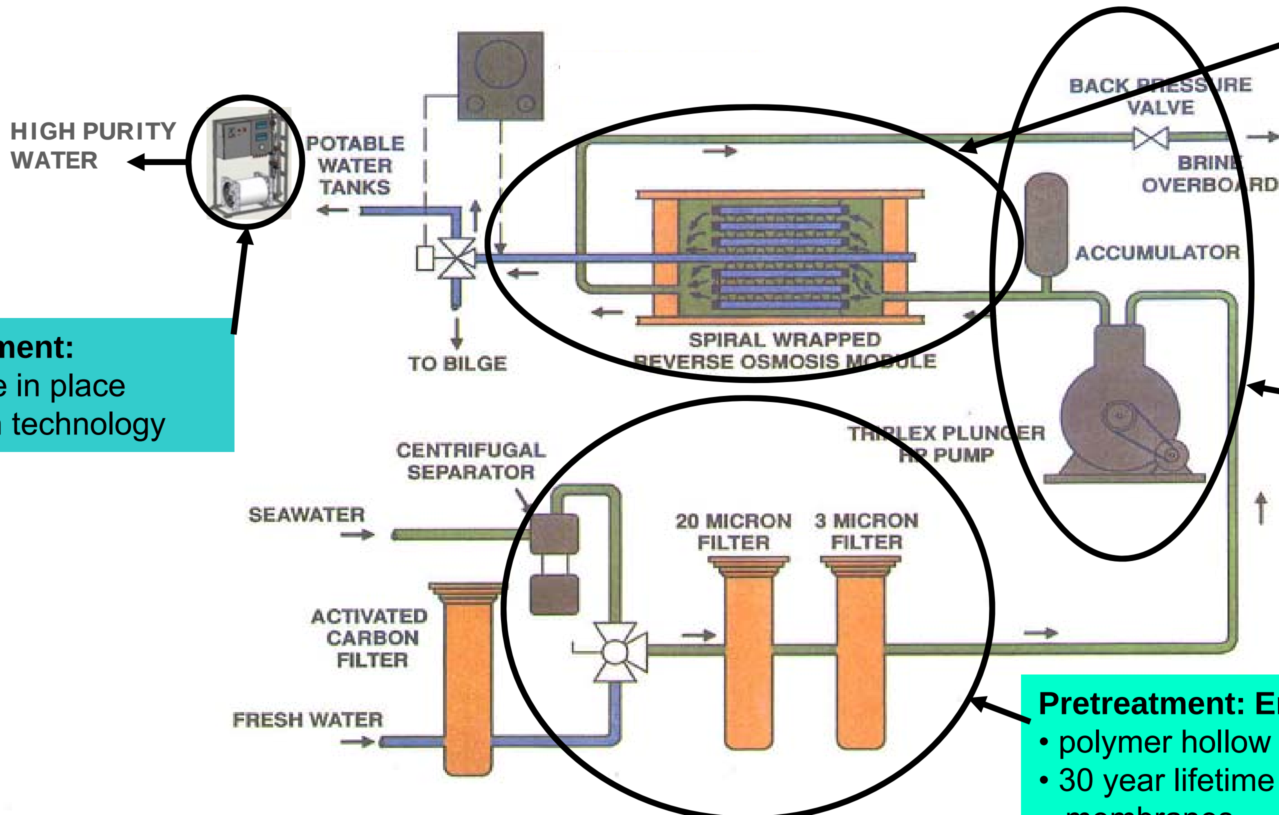
Post Treatment: Combination of multi-pass RO and ion exchange. Ion exchange is maintenance intensive.

Energy Reduction: NSRO has 80/20 split between brine and potable stream. 80% of water does not pass thru RO filter and leaves system at 1000 psi. Need to recover this energy.

Pretreatment: 3 micron particle size is not adequate in biologically active areas (slide 5). Filters last 1000 hrs in deep blue sea, 10's hrs in littorals. Creates a storage problem brings operational availability down greatly.

Enabling Technologies and S&T Issues

Desalination System: Enabling Technologies



Advanced Desalination:
- higher recovery based on better membranes, better prefiltration, antiscalants
- staged membranes
- higher flux membranes
- chlorine resistant membranes
- alternatives to RO

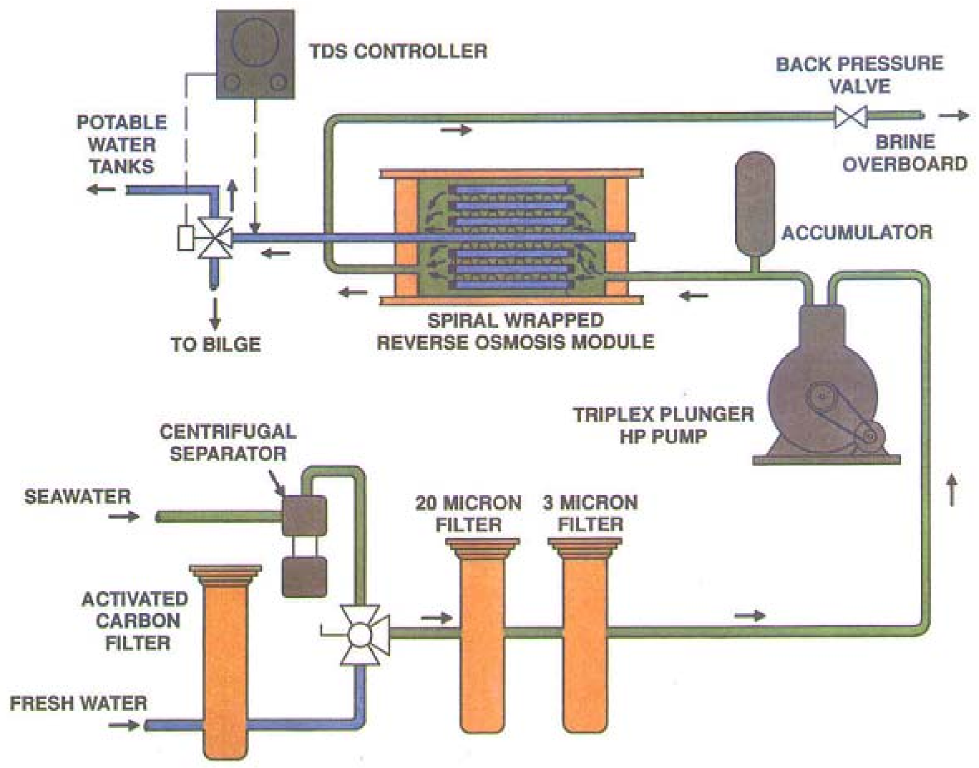
Post Treatment:
- regenerate in place deionization technology

Energy Reduction:
- energy or pressure exchanger to recover energy from pressurized waste brine stream
- smaller pump due to higher recovery
- smaller pump due to staged membranes

Pretreatment: Enabling Technologies
- polymer hollow fiber UF membranes
- 30 year lifetime ceramic MF/UF membranes
- Higher Flux membranes
- Electrocoagulation *in situ* flocculation
- Novel cleaning and backwash approaches

Enabling Technologies and S&T Issues

NSRO:
Navy Standard Reverse Osmosis



NSRO

PROS
- works well in deep blue sea
- simple linear process
- very few valves
- routine maintenance is changing filters when transmembrane pressure reaches limit
- robust construction standards
- no chemical use

CONS
- system does not work well enough when source waters have suspended solids
- system is not energy efficient
- system does not have diagnostic capabilities

Design Considerations

- Operated by sailors with little specific training therefore:
  - manning and maintenance needs to be minimal, simple
  - process flow needs to be intuitive, not a complete black box
- Space on ship is limited
  - unit must be compact
  - 6 months of logistics items must be stored (filters, chemicals, etc…)
- Deployments 6 months, possibly 9-12 months, dry dock cycle 7 -12 yrs
  - minor and major maintenance should fit these intervals
- Hazardous materials use and storage must be minimized
  - possibly generate oxidants, coagulants on site
- Energy efficiency is always desired, but energy to purify water is insignificant relative to propulsion and other needs.

Program Plan/ Phasing (BAA pages 6-9)

Phase I: Concept System Architecture Design

- 6 month program to develop system design
- Kick-off meeting, reviews after 3 and 5 months
- Go/ No Go Decision
- Deliverables: technical report, Level 1 Conceptual/Developmental design drawings, major components and parts list, government rights to Conceptual Level drawings

Clarifications:

- For desalination systems, *open architecture* primarily means don't specify unique membranes or other parts for which the Navy would be the only customer. It is preferred to go further such that acceptable performance can be obtained with membranes/ components from a number of vendors. In the long run, being able to easily replace pumps or systems is desired.

- *Government Furnished Information* could be: knowledge of specific shipboard space constraints, piping; suggestions for corrosion resistant materials; suggestions for making system robust; suggestion of components or practices that have worked well for the Navy; etc…

ONR Future Naval Capability: Advanced Shipboard Desalination

Program Plan/ Phasing (BAA pages 6-9)

5.7.1 Technical Data Packages, TDP Levels.

Phase I minimum government purpose rights

5.7.1.1 Conceptual level - A conceptual design TDP shall consist of those TDP elements necessary to define design concepts in graphic form, and include appropriate textual information required for analysis and evaluation of those concepts. The data will generally consist of simple sketches/models, artist renderings and/or basic textual data.

Phase II minimum government purpose rights

5.7.1.2 Developmental level - A developmental prototype/limited production TDP shall consist of those TDP elements necessary to provide sufficient data to support the analysis of a specific design approach, the fabrication of prototype materiel for test or experimentation, and limited production by the original design organization or with assistance from the original design organization.

Phase III minimum government purpose rights

5.7.1.3 Production level - A production level TDP shall consists of those TDP elements necessary to provide the design, engineering, manufacturing, inspection, packaging and quality assurance provisions information necessary to enable the procurement or manufacture of an item. The product shall be defined to the extent necessary for a competent manufacturer to produce an item, which duplicates the physical, interface, and functional characteristics of the original product, without additional design engineering effort or recourse to the current design activity. Production data shall reflect the approved, tested, and accepted configuration of the defined delivered item.

Program Plan/ Phasing (BAA pages 6-9)

Phase II: TRL 5 System Demonstration

- 12 month program to develop system design
- Bi-monthly review meetings
- Build and deliver TRL 5 proof of concept system to Navy facility by start of month 9 for testing
- Go/ No Go Decision
- Deliverables: technical report, government purpose rights through Level 2 Developmental Drawings

Clarifications:

- *Factory Performance and Safety testing*: Make sure unit is designed and built with common safety practices in mind and is tested prior to delivery.

- *Government Furnished Equipment:* conceivably government could provide alternative components to be utilized in the demonstration units; possibly successful components from the Phase I efforts.

- *TRL 5 level demonstrator:* It is desired for this unit to demonstrate the compactness, layout, and access of the eventual TRL 6/7 unit

Technology Readiness Levels, TRL

BA1 6.1

1. Basic principles observed and reported.

   Lowest level of technology readiness. Scientific research begins to be translated into applied research and development.

2. Technology concept and/or application formulated Invention begins.

   Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof to support the assumptions.

BA2 6.2

3. Analytical and experimental critical function and/or characteristic proof of concept.

   Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology.

4. Component and/or breadboard validation in laboratory environment.

   Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system.

BA3 6.3

5. Component and/or breadboard validation in relevant environment.

   Fidelity of breadboard technology increases significantly. The basic technological components are integrated so that device can be tested in a simulated environment.

6. System/subsystem model or prototype demonstration in a relevant environment.

   Representative model or prototype system, which is well beyond that of TRL 5 and is tested in a real or simulated operational environment.

Program Plan/ Phasing (BAA pages 6-9)

Phase III: TRL 6/7 System Demonstration

- 18 month program to develop system design
- Quarterly review meetings
- Build and deliver TRL 6/7 technology demonstrator to Navy facility by start of month 13 for testing
- Deliverables: demonstration unit with manuals, default is government purpose rights to Production Level drawings and supporting documentation

Clarifications:

- *Robust Military System*: built from highly corrosion resistant materials and non-flammable materials, built to pass shock and vibration requirements, EMI, etc…

Award Information (pages 11-12)

Desired Systems

1. 4000 gallon per day single pass seawater RO
   - Smaller ships could be in littoral waters, Navy need
   - Size, weight and efficiency metrics are hardest to achieve here
   - Full use of state-of-the-art large scale capabilities difficult

2. 18,000 gallon per day single pass seawater RO
   - A size that could see broad use on many ships.
   - Current NSRO is 12,000 gpd and is most deployed unit

3. 100,000 gallon per day mostly single pass RO
   - Larger units should be platform for more advanced technologies.
   - Should be easiest to meet weight and size metrics

Award Information (pages 11-12)

Desired Systems

1. 4000 gallon per day single pass seawater RO
2. 18,000 gallon per day single pass seawater RO
3. 100,000 gallon per day mostly single pass RO

Navy Needs for these systems

- Navy has ships that require anywhere from 3000 gpd to 500,000 gpd.
- Water needs are often for both potable and higher purities of water.
- Demonstration units could be deployed to new construction or as backfits to replace distillers or NSRO-type units.
- Specifications in the BAA are somewhat generic for a unit of a given size. By phase II and phase III shipboard testing opportunities will be solidified along with more specific dimensional constraints.

Award Information (pages 11-12)

Anticipated **Number of Awards and Award Values**

Unit Size	4000 GPD	18,000 GPD	100,000 GPD
no. of awards	1 to 4	0 to 2	1 to 2
no of Phases II	1 to 2	0 to 2	1 to 2
no. of Phase III	1 to 2	0 to 2	0 to 1
phase I cost	$125k	$150k	$200k
phase II cost	$225k	$300k	$1.2M
phase III cost	$350k	$500k	$2.0M
total cost**	$700k	$950k	$3.4M

** projected maximum award values in BAA
* Estimated total Funding under BAA is $6.9M

Award Information (pages 11-12)

Last Paragraph

In the case of funded proposals for the production and testing of prototypes, ONR may during the Contract period add a contract line item or contract option for the provision of advanced component development or for the delivery of additional prototype units. However, such a contract addition shall be subject to the limitations contained in Section 819 of the National Defense Authorization Act for Fiscal Year 2010.

- ONR has the now has legal authority to contract with 6.4 or 6.5 funding to aid in the transition process. It may be that funding or tasking necessary to test a prototype on a ship could be provided to the performer with an expansion of an ONR award as opposed to a new award from the sponsoring ship office.

Page 14: Each White Paper and Full Proposal shall contain information for only one capacity demonstration system. If your intent is to propose to develop more than one capacity demonstration system, then a separate White Paper and Full Proposal shall be submitted for each capacity system.

ONR FNC
Shipboard Desalination Demonstrators

Presented by:

Mike Evonick
Office of Naval Research
(360) 830-0475   michael.evonick@navy.mil

U.S. Office of Naval Research Industry Day
March 31, 2011 Hyatt Regency, Long Beach, CA

WHITE PAPERS

- White Papers are required prior to submitting a Full Proposal. Each White Paper will be evaluated by the government to determine whether the research proposed appears to be of "particular value" to the Department of the Navy.

- Each White Paper and Full Proposal shall contain information for only one capacity demonstration system. If your intent is to propose to develop more than one capacity demonstration system, then a separate White Paper and Full Proposal shall be submitted for each capacity system.

- No more than eight (8) single-sided pages (excluding cover page and resumes). White Papers exceeding the page limit may not be evaluated.

White Papers-cont

- Electronic e-mail submissions shall be accepted up to the date and time stated in the BAA. Hard copies will not be accepted.
- Pay attention to White Paper Format, Submission, and Content as stated in the BAA.
- No more than 8 single-sided pages excluding cover page and resumes.
- A maximum five (5) page technical section. Reminder to address issues mentioned in the Technical Concept and Operational Utility Assessment areas of the Full Proposal format.
- Those having particular value will be encouraged to submit detailed technical and cost proposals. There is no assurance of award. If advised that proposed technology is of no particular value, you may still choose to submit a full proposal. However, the White Paper evaluation is usually a strong indicator of how a full proposal on the same project would be rated.

FULL PROPOSALS

- Each Full Proposal and White Paper shall contain information for only one capacity demonstration system. If your intent is to propose to develop more than one capacity demonstration system, then a separate White Paper and Full Proposal shall be submitted for each capacity system.

- All full proposals must use both ONR's Technical and Cost Proposal Template as well as its Cost Proposal Spreadsheet. Both the Template and the Spreadsheet have instructions imbedded into them that will assist in completing the documents.

- Note that the sections in the Technical and Cost Proposal Template for "Future Naval Relevance" and "Operational Naval Concept" are not required for this solicitation.

Full Proposals -cont

- The following additional guidance is provided when completing the sections for "Technical Approach and Justification" and "Operational Utility Assessment Plan" (BAA pages 16-17).

- The text boxes in the template do not allow the use of figures. Proposals under this BAA are expected to require flow diagrams and other figures. It is allowed for this one section "III. Technical Content, I. Technical Approach and Justification" to be Submitted as a properly titled PDF attachment not to exceed 15 pages for easy inclusion of figures on the part of the proposal submitter and for improved readability. Note in the template boxes that the input was presented as an attachment and state the file name.

Full Proposals –cont

- The Cost Proposal Spreadsheet can be found by following this link:
- http://www.onr.navy.mil/Contracts-Grants/submit-proposal/contracts-proposal/costproposal.aspx.
- Click on the “proposal spreadsheet” link and save a copy of the spreadsheet. Instructions for completion have been embedded into the spreadsheet. Any proposed options that are identified in the Technical and Cost Proposal Template, but are not fully priced out in the Cost Proposal Spreadsheet will not be included in any resulting contract or other transaction.
- Page Limitations – There is no overall page limitation for the “Technical and Cost Proposal Template”. However, the template includes subsection limitations.

Full Proposals –cont

- Also, note the page restriction on the attachment related flow diagrams and other figures. Other subsection limits are provided in the template.

- Proposals with subsections and attachment exceeding these page limitations may not be evaluated. There are no page limitations to the Cost Proposal Spreadsheet.

- Electronic files submitted on CD must be submitted in the pdf format for the Technical and Cost Proposal Template, in Microsoft Excel 2007 compatible format for the Cost Proposal Spreadsheet, and in Microsoft Office or pdf compatible format for any attachments, although pdf compatible formats are preferred.

Anticipated Schedule

• White Paper Due	5/2/2011
• Notification of evaluation	5/16/2011
• Full Proposals Due	6/15/2011
• Notification of Selection	7/15/2011
• Awards	1/7/2012

- Materials submitted through the U.S. Postal Service, for example, may take seven days or more to be received, even when sent by Express Mail.

Submission of Full Proposals

- The only acceptable methods for submission of full proposals are 1) by mailing to the technical point of contact by the United States Postal Service (USPS), 2) via a commercial carrier (FedEx, DHL, and UPS), or 3) by hand delivery. NOTE: Full proposals sent by email, fax, or other means not in accordance with the requirements herein will not be considered.

- Delivery of materials by USPS, even when sent as Express Mail, may take a week or more due to current security procedures.

Evaluation Criteria

- Award decisions will be based on a competitive selection of proposals resulting from a scientific and cost review.
- See four technical evaluation factors (p 20-21).
- Reasonableness and realism of the proposed costs to meet the proposed objectives.
- Technical Factors are significantly more important than the Cost Factor , with the Technical Factors all being of equal value.

Submission of Questions

- All questions shall be submitted in writing by electronic mail.
- Questions regarding White Papers must be submitted by 2:00 p.m. Eastern Time two weeks before the date and time for receipt of White Papers. Questions after this date and time may not be answered and due date will not be extended.
- Questions regarding Full Proposals must be submitted by 2:00 p.m. Eastern Time two weeks before the date and time for receipt of Full Proposals. Questions after this date and time may not be answered, and due date will not be extended.

GOVERNMENT TESTING CAPABILITES FOR THE EVALUATION OF DELIVERED BAA PRODUCTS

ONR Industry Day- BAA 11-010

Demonstration System Development for Advanced Shipboard Desalination FNC

March 31, 2011 Long Beach, CA

Presented by:

Bill Varnava

NAVFAC ESC, 805-982-6640

BACKGROUND – Seawater Desalination Test Facility (SDTF)

The SDTF provides research, development, test and evaluation, and training support for water purification equipment. It is located at the entrance to the port at Port Hueneme, CA providing direct access to natural Pacific Ocean water using an open-ocean intake.

The SDTF is managed by the Amphibious and Expeditionary Department of the NAVFAC Engineering Service Center, Naval Base Ventura County.

Naval Base Ventura County
Port Hueneme, CA

BACKGROUND – Origins and Mission

- Origins: The SDTF was originally established in 1983 at the Naval Civil Engineering Laboratory (NCEL), a predecessor to NAVFAC ESC. In January 2000, the SDTF was relocated to the harbor entrance at Naval Base Ventura County, Port Hueneme, CA.

- Mission: The mission of the SDTF is to provide a real world test environment for long term evaluation of desalination equipment and other water purification components including pumps, pretreatment filters, and energy recovery devices. The test data collected provides DoD and private sector developers with real world feedback on the reliability and durability of key system components.

SDTF FACILITY SPECIFICATIONS

- Location: Adjacent to entrance of Port Hueneme Harbor with direct access to seawater
- Area: Occupies approximately 0.75 acres along waterfront (approx. 125 ft wide x 260 ft long).
- Tent: Covered 3500 ft^2 concrete pad, trenches, electricity (208/460 V) instrument room, shop tools
- Outdoor Pad: 1800 ft^2 concrete test pad with sunshade cover, 460 V/3 phase power
- Intake pier: provide access to harbor (8 ft wide x 65 ft. long)
- Intake pump house: (12 ft x 12 ft), 2 pumps up to 350 gpm flow
- Storage tanks: 5000 gallon raw seawater, 2500 gallon product, 20K gallon fresh water bladder
- Power: 3 phase, 460 V, 1000 A / 208 V, 800 A
- Compressed Air: 2 compressors available
- Discharge piping: 2 outfalls/sumps, 24 in. diameter, brine/product recombined

SDTF TEST EQUIPMENT

- **Pretreatment Skids**
  - –MEMCOR PVDF Microfiltration System (20 gpm)
  - –MEMCOR Polypropylene MF system- TWPS (50 gpm)
  - –Koch Polysulfone UF system- LWP (4 gpm)
  - –Multimedia and cartridge filter system (80 gpm)
  - –Misc. backwashable strainers

- **Reverse Osmosis Skids**
  - –4 inch x 40 in long RO test skids (3 systems)
  - –2.5 inch x 40 in long RO test skid (4 systems)
  - –8 inch x 40 in long RO test skid (1 system)

- **Ancilliary Test Equipment**
  - –Electrolytic chlorine generator
  - –Variety of injection pumps, tanks, hoses

SDTF INSTRUMENTATION

- Turbidity meters (Hach Filtertrak 660, 1720)
- pH meter
- Conductivity meter (Myron L)
- ORP meter
- Fluorescence meter (chlorophyll A and polycoerythrin)
- Dissolved Oxygen meter
- Temperature sensor
- Particle counts (> 2 micron)-
- Silt Density Index (SDI)- EZ SDI system
- Resistivity meter
- Deionized Water system
- Hand held chemical analyzer (chlorine, iron, multi ion)-Hach DR850 colorimeter

ANALYTICAL CAPABILITIES

- **Can conduct following water quality analyses in house through ESC chemist:**

- **Chloride (Cl-)**
- **Total Carbon Dioxide (TCO2)**
- **Total Suspended Solids (TSS)**
- **Total Dissolved Solids (TDS)**
- **Silica (SiO2)**
- **Chlorine – Free and Total (Cl2)**
- **Titrations, filtration and various wet chemistry techniques**

Instrumentation:

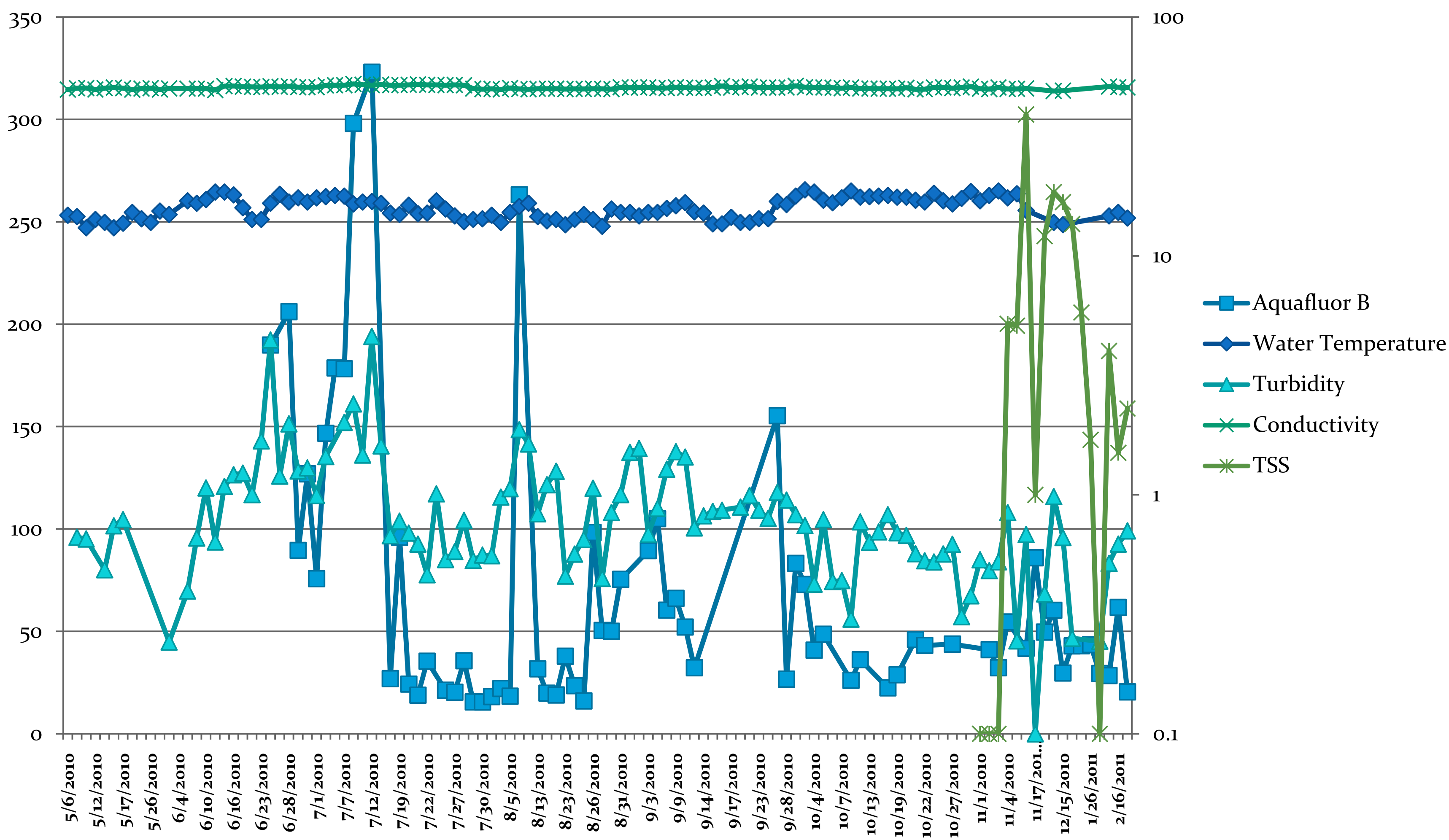
- **We have the following major instrumentation for analysis of materials:**
- **FTIR – identification of organic (and some inorganic) solids, liquids, and gases**
- **UV-VIS – colorimetric analysis of liquids and solids, reaction studies**
- **ICP – emission spectroscopy technique for analyzing elements in solution**
- **DMA – mechanical flexural modulus information of solids**
- **SEM – microscopic analysis of material structure**
- **Instron/Baldwin – tensile and compression properties of solids (e.g. concrete, steel)**

SDTF – Raw Water Characteristics

- Raw Water Quality: The SDTF utilizes an open ocean intake to draw in raw water to the facility.

Raw Seawater Parameter	Measured Values
Turbidity	0.5 - 3 NTU (1.0 NTU)
Total suspended solids (TSS)	0.5 - 15 mg/L (5mg/L)
Total dissolved solids (TDS)	35,000 - 38,000 mg/L
Temperature	53 - 70 °F
Total Carbon Dioxide, TCO_2	110-120 mg/L
pH	7.8-8.0
Total organic carbon (TOC)	0.0 – 2.0 mg/L
Silica	0.6 -1.5 mg/L
Chloride concentration (Cl^-)	19,680 mg/L

Raw Seawater
Water Quality Data –SDTF Port Hueneme



SDTF DISCHARGE PERMIT

- SDTF has discharge permit from State of California
  - –1,000,000 gallons per day of raw seawater flow
  - –Monitor daily flows, conduct quarterly samples
- Recombine the product and brine water
  - –Water processed is used for test purposes only
  - –Store RO product water for system flushing and cleaning
- Limits on discharge for chemicals and metals
  - –Copper
  - –Chlorine
  - –Nickel
  - –Backwash wastes, flux maintenance
  - –Sanitary sewer connections

SDTF GENERAL OPERATIONS

- Equipment usually run 24 hrs day / 7 days a week
- SDTF staff on site Mon-Fri for data collection, maintenance
- Open ocean intake with coarse strainer
- Equipment may be exposed to outdoor elements
- Occasional algae blooms or red tide events during summer
- Data sheets and log books for each system tested
- Typical parameters monitored during testing include
  - pressure,
  - flowrates
  - temperature
  - water quality
  - operating time

SDTF SUPPORT TO FNC PROGRAM

- **SDTF to be used as primary test bed for FNC evaluations of developed products from BAA 11-010.**
- **BAA Phase II (4 months)-TRL 5**
  - **Evaluation of proof of concept demonstration system on natural seawater.**
- **BAA Phase III (6 months)-TRL 6/7**
  - **Evaluation of refined demonstration system on natural seawater.**
- **Equipment Specifications**
  - **Size**
  - **Flow requirements**
  - **Air Requirements**
  - **Power**
  - **Chemicals/Consumables**
  - **Special equipment**
  - **Materials of construction**

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