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A Comparison of Military and Commercial Submersible Systems, Cost Environments, and Methods for Estimating Submersible Development and Production Costs

G.C. Bell - MCR LLC
Brian Harris - U.S. Navy
Janet Vacca-LeBoeuf - U.S. Navy

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- Government Submarine Programs and Shipyards
- Commercial Submersible Programs and Suppliers
- Continuing Need for SOF Submersibles
- Possible Submersible Program Opportunities
- Potential Scope for Cost Savings
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OVERVIEW

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- WBS Structure for Parametric Model
- NRE Prime Mission Product & Components
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- Conclusions

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Submarine Systems – Descriptions and Characteristics

U.S. Navy Submarines:

All U.S. Navy fleet submarines are large, nuclear powered vessels. The SSBN and SSN Class submarines all exceed a billion dollars per unit, less weapons. Only two yards are capable of building these complex ships; Electric Boat Division (CT) of General Dynamics and the Newport News Division (VA) of Northrop Grumman.

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Submarine Systems – Descriptions and Characteristics

U.S. Navy/SOF Submersibles:

Navy/SOF submersibles are used to insert and extract teams of Navy SEALs into enemy littoral zones or to perform reconnaissance and other special missions in coastal waters. Submersibles can be transported by large submarines using Dry Deck Shelters (DDS) or are air- transportable via cargo aircraft.

SDV – Seal Delivery Vehicle - "Wet" Submersible, designed to carry several combat-equipped Navy SEALs in scuba gear. The SDV development was begun in 1992, and it weighs roughly 3 tons (dry). The SDV vessels were designed and fabricated at a U.S. Navy facility.

ASDS – Advanced Seal Delivery System - "Dry" Submersible, capable of carrying multiple combat-equipped Navy SEALs. A large vessel, (55 tons) the ASDS program began in 1997, with the first unit tested in 2003.
Only one unit was built, and its many technical problems and cost overruns resulted in termination. The ASDS was designed and fabricated at Northrop Grumman's Newport News shipyard.

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Submarine Systems – Descriptions and Characteristics

Example – Wet Submersible

Around 6,000 lbs Gross Weight

Example - Dry Submersible

Around 110,000 lbs Gross Weight

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Government Submarine Programs and Shipyards

Navy prime contractors are large businesses, with extensive facilities, infrastructure and overheads. Their work forces are organized in functional divisions and departments that perform specialized and repeatable tasks. Many of their departments are unionized, with work rules and norms established via collective bargaining. Prime contractors share certain characteristics:

- They are expensive – cost per labor hour is high.
- Multiple layers of management affect enterprise productivity.
- They rely on networks of special suppliers, with prime contractor profits applied on top of supplier profits.
- They are familiar with Government processes, specifications, and reviews, and are prepared to deal with changes required by the Government. Among these specifications is NAVSEA P9290, which was implemented after fatal accidents to provide safe undersea systems.
- They are familiar with and are organized to create and produce data products and support items required by the Government.

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Commercial Submersible Programs and Suppliers

Commercial submersible builders are small, entrepreneurial businesses, with small facilities, minimal infrastructure and low overheads. Aside from a very small leadership element, their work forces are composed of small groups of highly skilled people with multiple skill sets. Commercial builders operate in an episodic way: periods of active construction are followed by periods where product support activities dominate.

- **Their salary costs are comparable to large businesses, but their overheads and benefits tend to be very low. There are very simple management structures. Labor is highly productive.**
- **They rely on a few special suppliers, but most of their purchased items are "maritime COTS."**
- **They are not familiar with Government processes, specifications, and reviews, and are not well prepared to deal with changes required by the Government. Commercial certification is in accordance with standards established by the American Bureau of Shipbuilding (ABS).**

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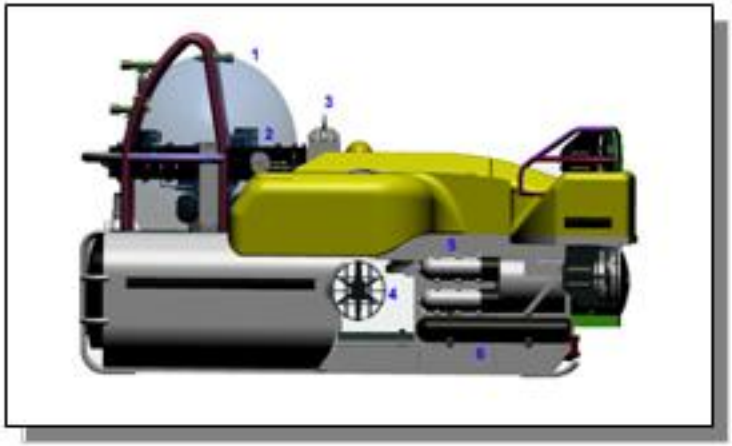
Commercial Submersible Programs and Suppliers

- They create and produce only those minimal data products and support items required to safely operate the submersible systems. They provide logistic support to commercial operators.
- Their network of customers includes:
  - Tourist operations/resort hotels
  - Recreation for wealthy individuals
  - The petroleum industry
  - Universities and Academic Institutions
  - Non-military Government Organizations



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The Continuing Need for SOF Submersibles

The ASDS submersible program was terminated after extraordinary technical failures, cost overruns, and an electrical fire that put the only vessel out of commission.

There continues to be a need for an ASDS-type submersible system, that would transport SEAL combat teams to enemy littoral spaces. After the ASDS experience, the U.S. military became interested in the apparent success (and affordability) of the commercial submersible industry. Could the Navy's Engineering and Acquisition practices and policies be modified to accommodate commercial paradigms and thereby capture significant program savings?

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Possible Submersible Program Opportunity

Characteristics - Dry Submersible Program for USSOCOM

25,000 – 30,000 lb Class Vessel, with production of as many as 6 or 8 units

Range: TBD

Speed: TBD

Payload Capacity: TBD

Endurance: TBD

Elements of Navy-Like Approach

- May require NAVSEA P9290 and limited MIL-SPECS
- Would require Military Electronics (NAV/Comm/Sensor/Controls & Displays) as GFE
- Would require favored battery technology (Ag-Zn or other) as GFE
- Would require data to support military organic support.

Elements of Commercial Approach

- ABS Classification
- Preference: small/agile/affordable commercial supplier
- Limit requirements changes and design reviews
- Define testing and acceptance criteria up-front.
- Provide support data for organic maintenance using commercial formats.

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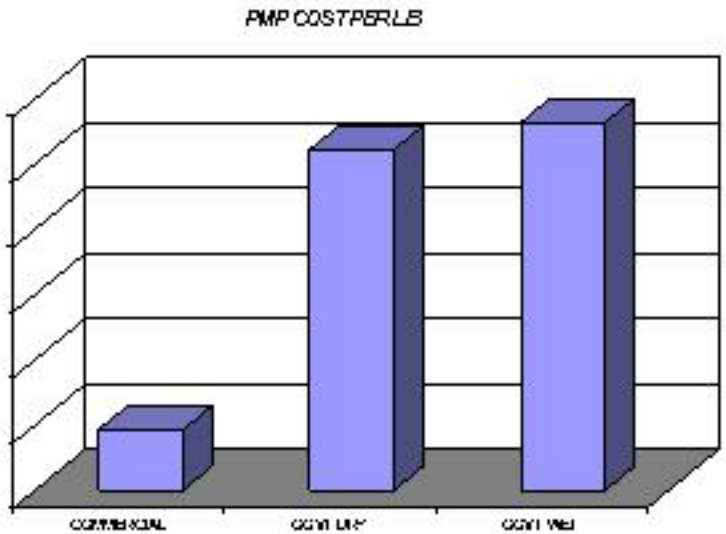
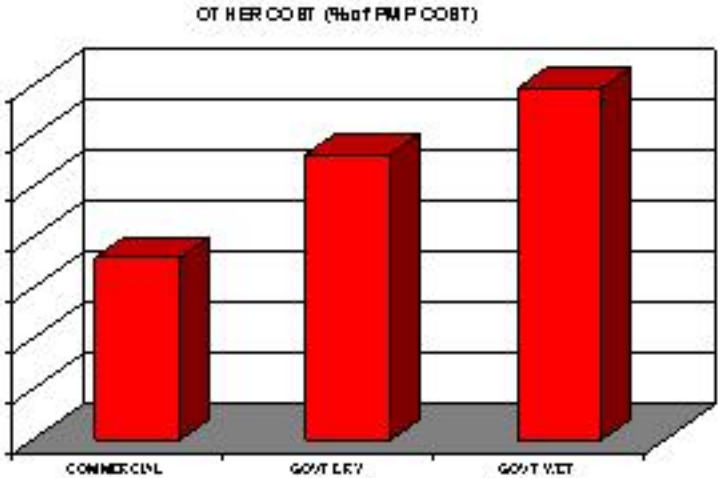
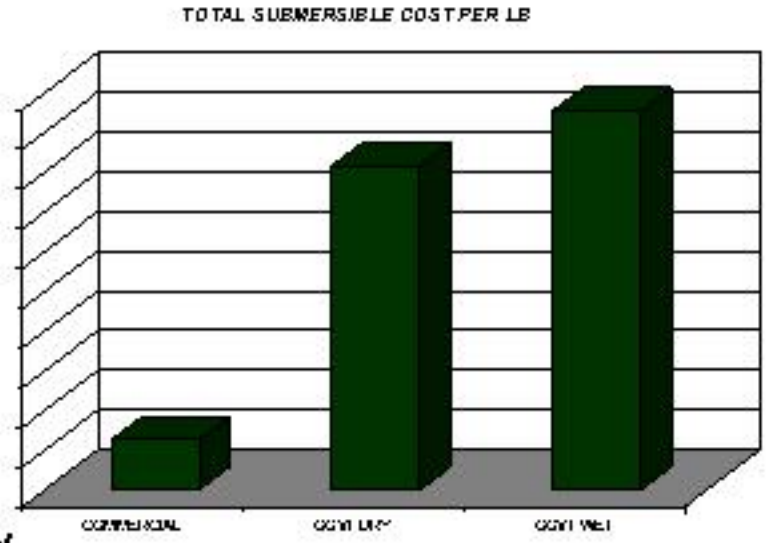
The Potential Scope for Cost Savings (Notional)





GOVERNMENT COST PENALTY	GOVT DRY	GOVT WET
PMP COSTS PER LB	5.6	6.1
OTHER COSTS AS % PMP	1.6	1.9
TOTAL COSTS PER LB	6.5	7.6

Commercial Submersible Cost difference: Roughly one fifth to one seventh of Government Program.



Note: Notional Savings based upon 3 dry submersible commercial programs, one wet Government, and one dry Government Submersible system.

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What Comprises the "Penalty" ?

- ***Indirect Rates***
  - Large Defense Contractors vs. Small Commercial Enterprise
- ***Labor Mix***
  - Specialized Labor vs. Cross-Trained Labor
- ***Additional and More Sophisticated Electronics***
  - Military sensors, navigation, and Communications vs. Limited Commercial Suite
- ***Ownership of Drawing Package***
  - Government interest vs. Commercial Practice
- ***Classification Standards***
  - P9290 vs. ABS (Schedule Impact)
- ***Management***
  - Multiple layers (Large Defense Contractors) vs. Austere Commercial Enterprise (Schedule Impact)
- ***Support Elements Designed for Less Trained Personnel***
  - Data (ie., Manuals) and training designed for high-turnover, military personnel vs. commercial logistic support

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Cost Analysis Approach: Analogy with Selected Interventions

Create Estimate by Adjusting Commercial Program History

- **Adjust Labor Costs:** Commercial submersible labor, cost structures, and experience are episodic and may not be sustainable. The Government's requirements could result in a new enterprise cost structure (rates, overheads, and management structures that resemble those of small to mid-size defense contractors.

- **Adjust Material Costs:** The Government imposition of MIL-Specs, pass-through cost reporting, or NAVSEA P9290 could impact the cost of purchased components and equipment.

- **Add GFE Equipment:** The commercial supplier has no relevant experience acquiring military electronics or Government specified battery systems. The contractor cost to install GFE must be added, as well as the Government outlays for the equipment.

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Cost Analysis Approach: Analogy with Selected Interventions

Create Estimate by Adjusting Commercial Program History

- **Added Management and Development Tasks:**
  The Government's conduct of design reviews and changes to requirements can add significant cost to the development program. The Government's requirements for test, evaluation, and acceptance also impact development costs.

- **Added Support Tasks: The contractor must develop data for operators and maintainers and training course-ware. The contractor must develop support equipment and establish a list of logical spares and quantities needed to support long term operational availability.**

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WBS Structure for Submersible Programs
Analogy Approach

See MIL-STD-881A (2005) p. 64-74 for dummy cost analogy/parametric and Appendix C for "other program costs" dummy cost. MIL-STD-881A can be found at:

http://www.acq.osd.mil/pm/current/policy/vault/MIL-HDBK-881A/MIL-HDBK-881A/WebHelp3/MIL-HDBK-881A%20-GIPS%20PUBLICATION%20FINAL%20100406.pdf

SYSTEM NAME	WEIGHT	N.R. COST	PRODUCTION COST*	TOTAL SYSTEM COMMITMENT OUTLAY
		Yr	Yr	
2.1 PRIME MISSION SYSTEMS				
2.1.1 HULL STRUCTURES (PN)				
2.1.2 PROPULSION PLANT (PN)				
2.1.3 ELECTRICAL PLANT (EL)				
2.1.4 COMMAND, CONTROL and SURVEILLANCE (CCS)				
2.1.5 AUXILIARY SYSTEMS (AS)				
2.1.6 OUTFIT AND FURNISHINGS (OF)				
2.1.7 OTHER (PLEASE SPECIFY)				
2.1.8 SYSTEM LEVEL INTEGRATION ASSEMBLY, CHECKOUT				
SUBTOTAL MISSION SYSTEMS COST				
OTHER PROGRAM COST ELEMENTS				
2.2 SYSTEM ENGINEERING & PROGRAM MGT				
2.3 SYSTEM TEST & EVALUATION (T&E)				
2.4 DATA				
2.5 TRAINING MATERIALS & SERVICE				
2.6 SUPPORT EQUIPMENT				
2.7 SPARE PARTS				
2.8 SITE ACTIVATION & INTERIMMAINTENANCE				
SUBTOTAL OTHER PROGRAM COST ELEMENTS				
OTHER PROGRAM TOTAL COST				

Notes:
Yr = Year or Midpoint Year
N.R. Cost = Non Recurring Cost through G&A
*Production cost through G&A for "Xth" (specify) unit

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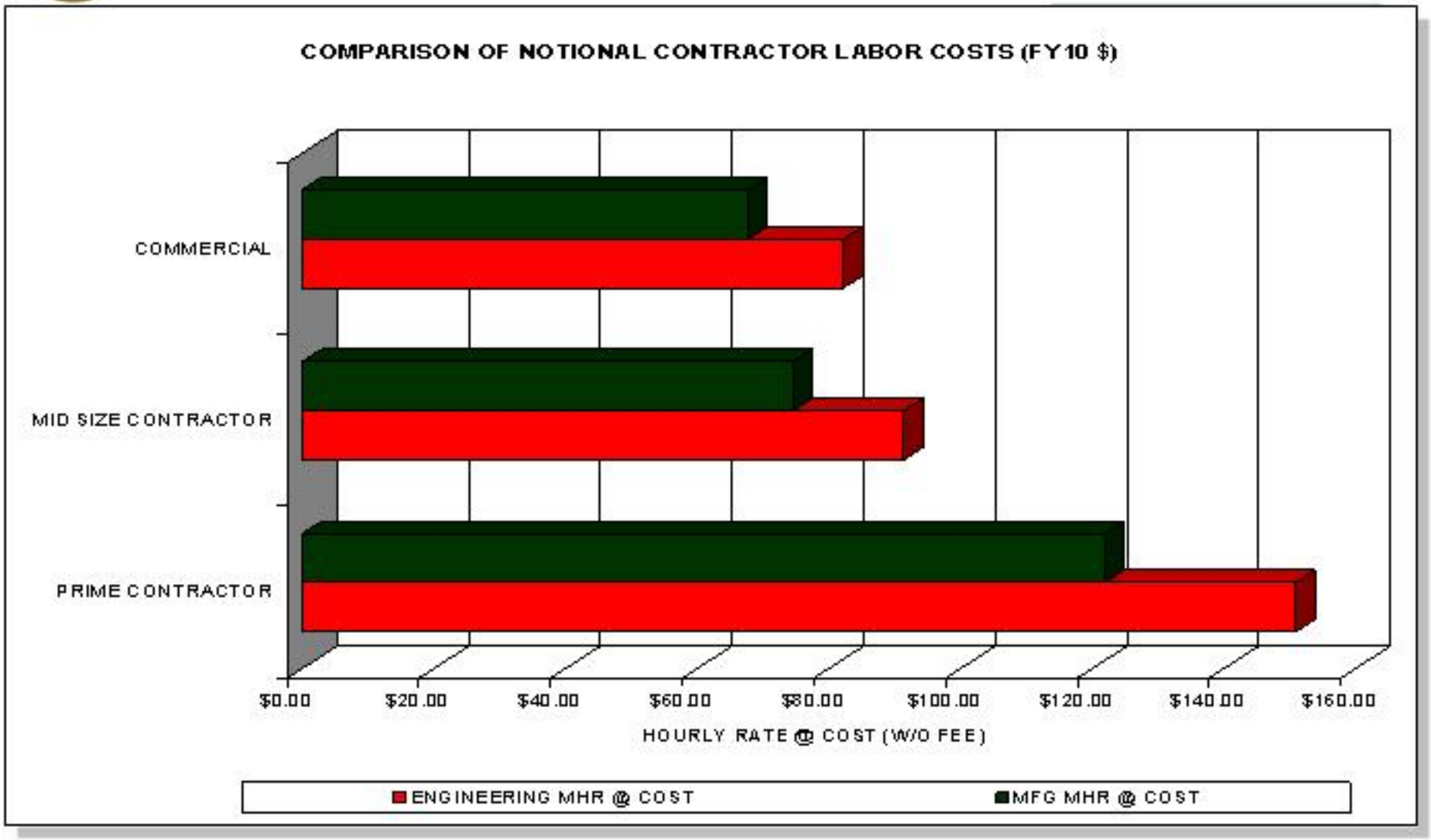
Comparison of Financial Structures (Notional)



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Affordability Opportunities

Prime Mission System and Engineering

Government vs. Commercial – Prime Mission System (Adjustment TBD)

Navy Contractors

- Governed by Mil-Specs
- NAVSEA P9290
- Small network of qualified suppliers
- Changing Requirements
- Multiple Design Reviews

Commercial Enterprise

- No Mil-Specs
- ABS Standards
- COTS and small network of special suppliers
- Stable Requirements
- Few Design Reviews

Government vs. Commercial – System Engineering (Adjustment TBD)

Navy Contractors

- NAVSEA P9290
- Changing Requirements
- Multiple Design Reviews

Commercial Enterprise

- ABS Standards
- Stable Requirements
- Few Design Reviews

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Affordability Opportunities

Test, Program Mgt, Product Support

Government vs. Commercial – Test & Evaluation Program (Adjustment TBD)

Navy Contractors

- Governed by Mil-Specs
- NAVSEA P9290
- Component Qualification Tests
- Elaborate & Extended

Commercial Enterprise

- No Mil-Specs
- ABS Standards
- Minimal Qualification Testing
- Minimal System tests (trials)

Government vs. Commercial – Product Support (Adjustments TBD)

Navy Contractors

- Elaborate Data & Training
- Support Equipment for Organic Maintenance
- Spares for extended Service Life (15-30 years)

Commercial Enterprise

- Simple Handbooks for operators, Contract Maintenance Support
- Very limited Support Equipment
- Spares are provided as part of Contract Maintenance
- Typical Service life 5-10 years.

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Cost Analysis Approach: Parametric Method

Create Estimate Using Cost vs. Weight and Cost vs. Performance CERs

- Collect and Normalize Cost Data

- Parametric Cost Model : Cost and weight data was collected for five commercial submersible programs and two Government programs. This allowed us to develop trends for development and production cost at the component and other cost levels.

- Comparison of Costs: Differences between commercial and Government programs result from technical, accounting, and administrative causes. The data were arrayed so that differences could be quantified and possible underlying causes identified.

- Development of Adjustments: The emerging program will employ a mix of traditional NAVSEA practices and commercial practices. What adjustment factors should be used to capture this "hybrid" environment?

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WBS Structure for Submersible Programs
Parametric Approach

See MIL-STD-881A (2005) p. 6A-74 for definitions of subsystems and Appendix I for "other program cost" definitions. MIL-STD-881A can be found at:

http://www.acq.osd.mil/pm/current/policy/docs/MIL-HDBK-881/A/MILHDBK881A/WebHelp3/MIL-HDBK-881A%20-%20PUBLICATION%20FINAL%20100406.pdf

SYSTEM NAME	WEIGHT	N.R. COST Yr	PRODUCTION COST* Yr	TOTAL SYSTEM COMPONENT COST*
2.1 PRIME MISSION SYSTEMS				
2.1.1 HULL STRUCTURES (PV)				
2.1.2 PROPULSION PLANT (PN)				
2.1.3 ELECTRICAL PLANT (EL)				
2.1.4 COMMAND, CONTROL and SURVEILLANCE (CCS)				
2.1.5 AUXILIARY SYSTEMS (AS)				
2.1.6 OUTFIT AND FURNISHINGS (OF)				
2.1.7 OTHER (PLEASE SPECIFY)				
2.1.8 SYSTEM LEVEL INTEGRATION, ASSEMBLY, CHECKOUT				
SUBTOTAL MISSION SYSTEMS COST				
OTHER PROGRAM COST ELEMENTS				
2.2 SYSTEM ENGINEERING & PROGRAM MGT				
2.3 SYSTEM TEST & EVALUATION (T&E)				
2.4 DATA				
2.5 TRAINING MATERIALS & SERVICE				
2.6 SUPPORT EQUIPMENT				
2.7 SPARE PARTS				
2.8 SITE ACTIVATION & INTERIM/ITR SUPPORT				
SUBTOTAL OTHER PROGRAM COST ELEMENTS				
OTHER PROGRAM TOTAL COST				

Notes:
Yr = Year or Midpoint Year
N.R. Cost = Non Recurring Cost through G&A
*Production cost through G&A for "Xth" production unit

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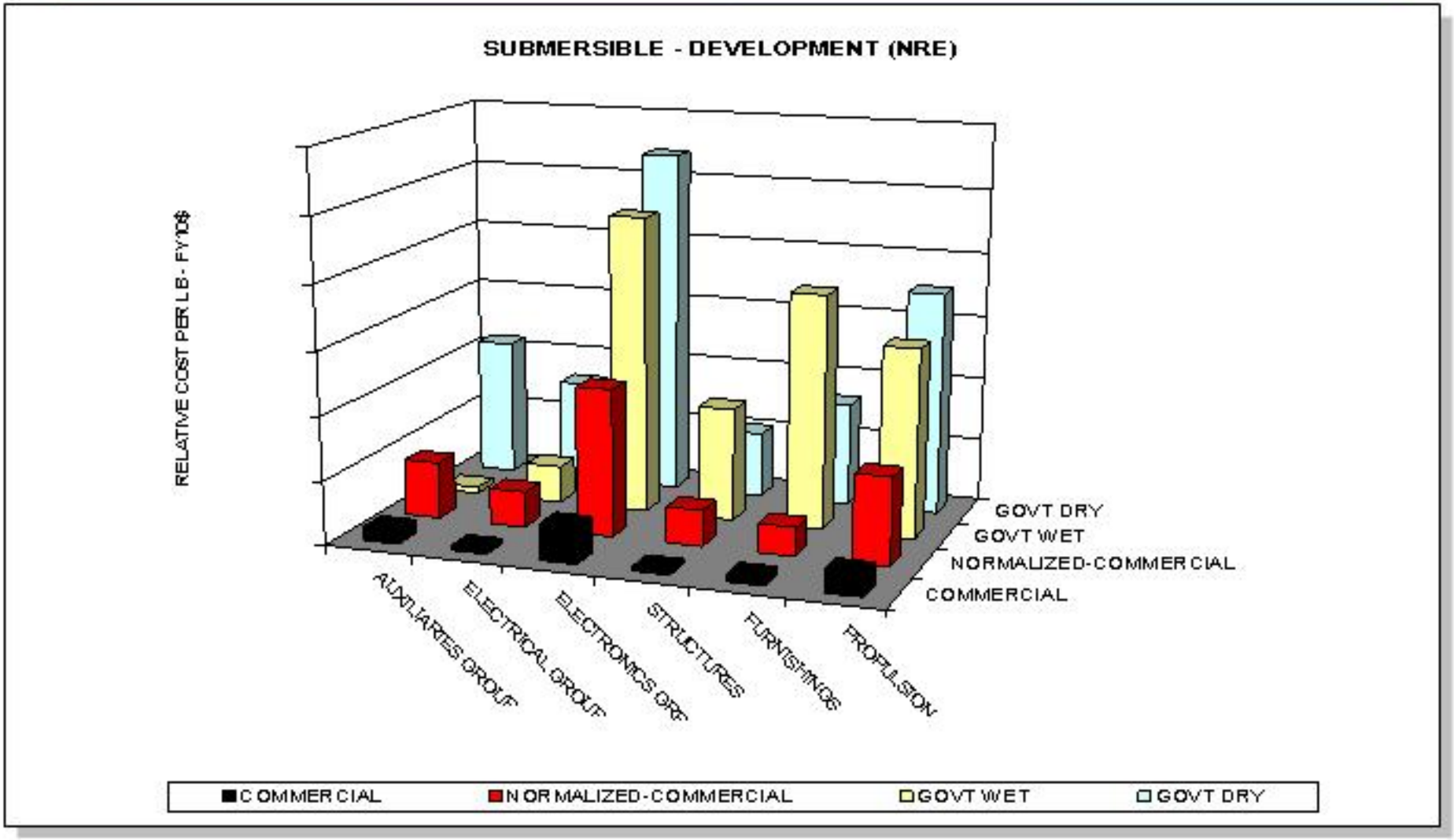
SUBMERSIBLE DEVELOPMENT (NRE) COMPONENT SYSTEMS



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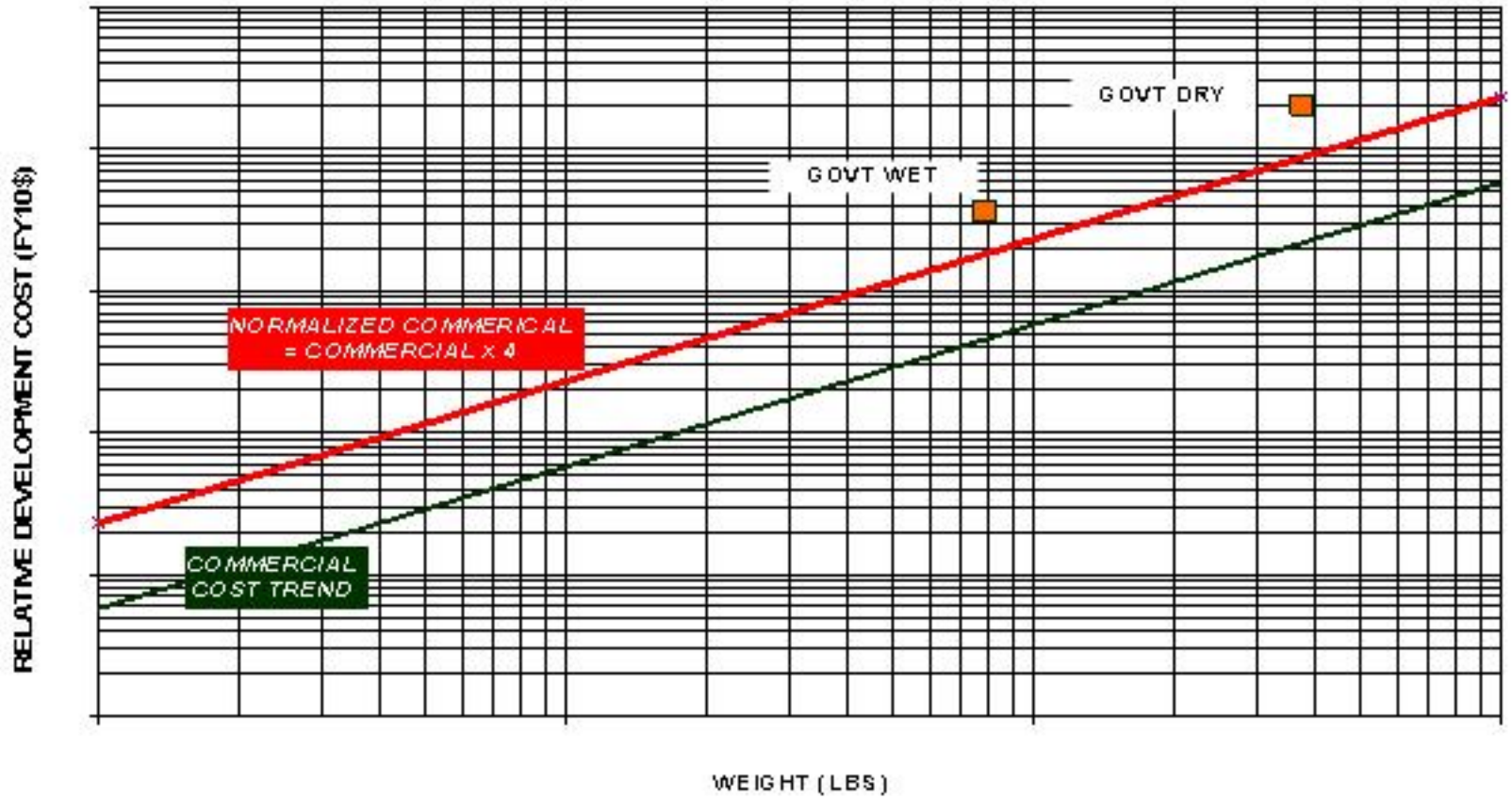
SUBMERSIBLE DEVELOPMENT (NRE) COMPONENT SYSTEMS



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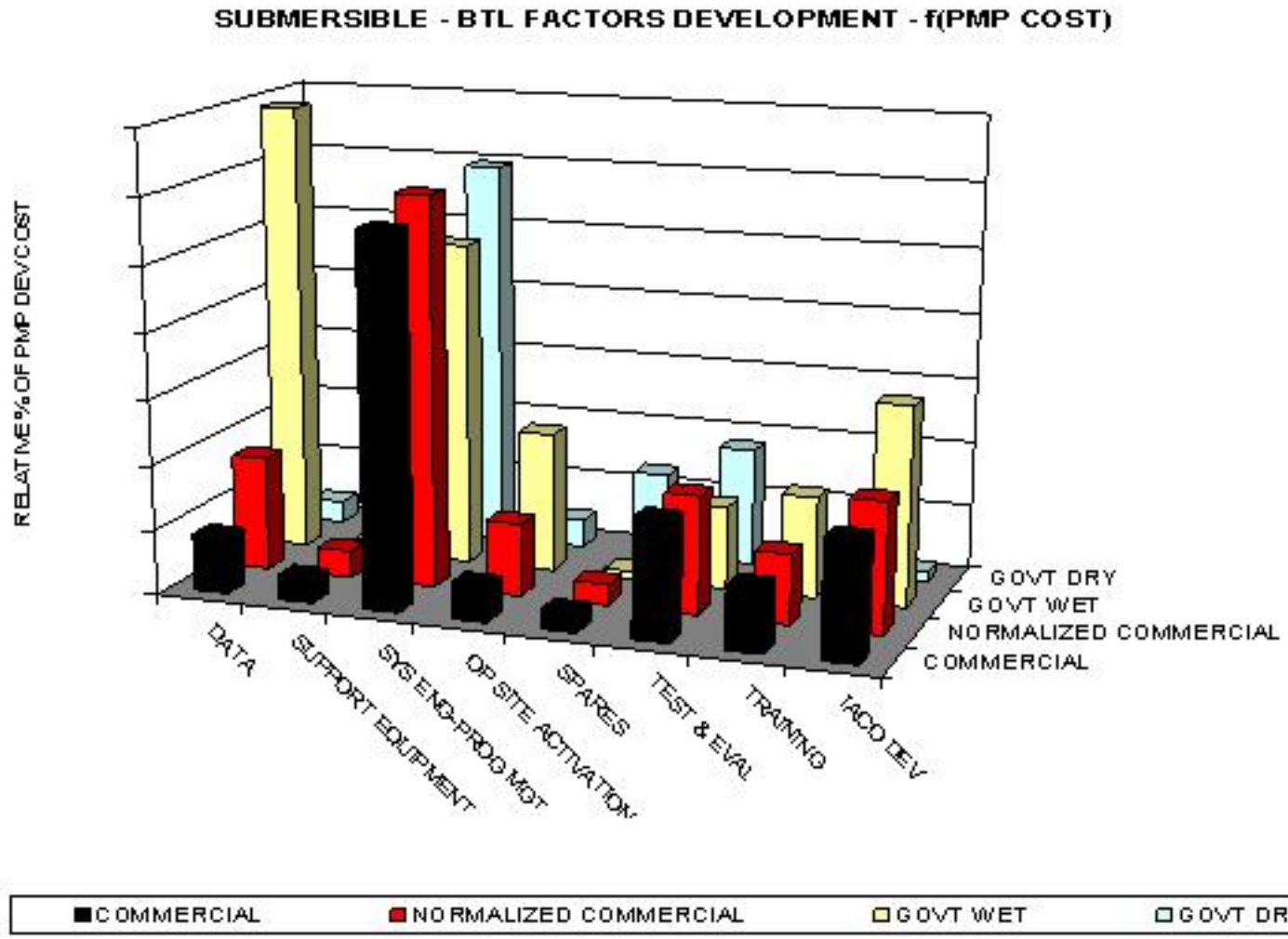
SUBMERSIBLE DEVELOPMENT OTHER COSTS (BTL)



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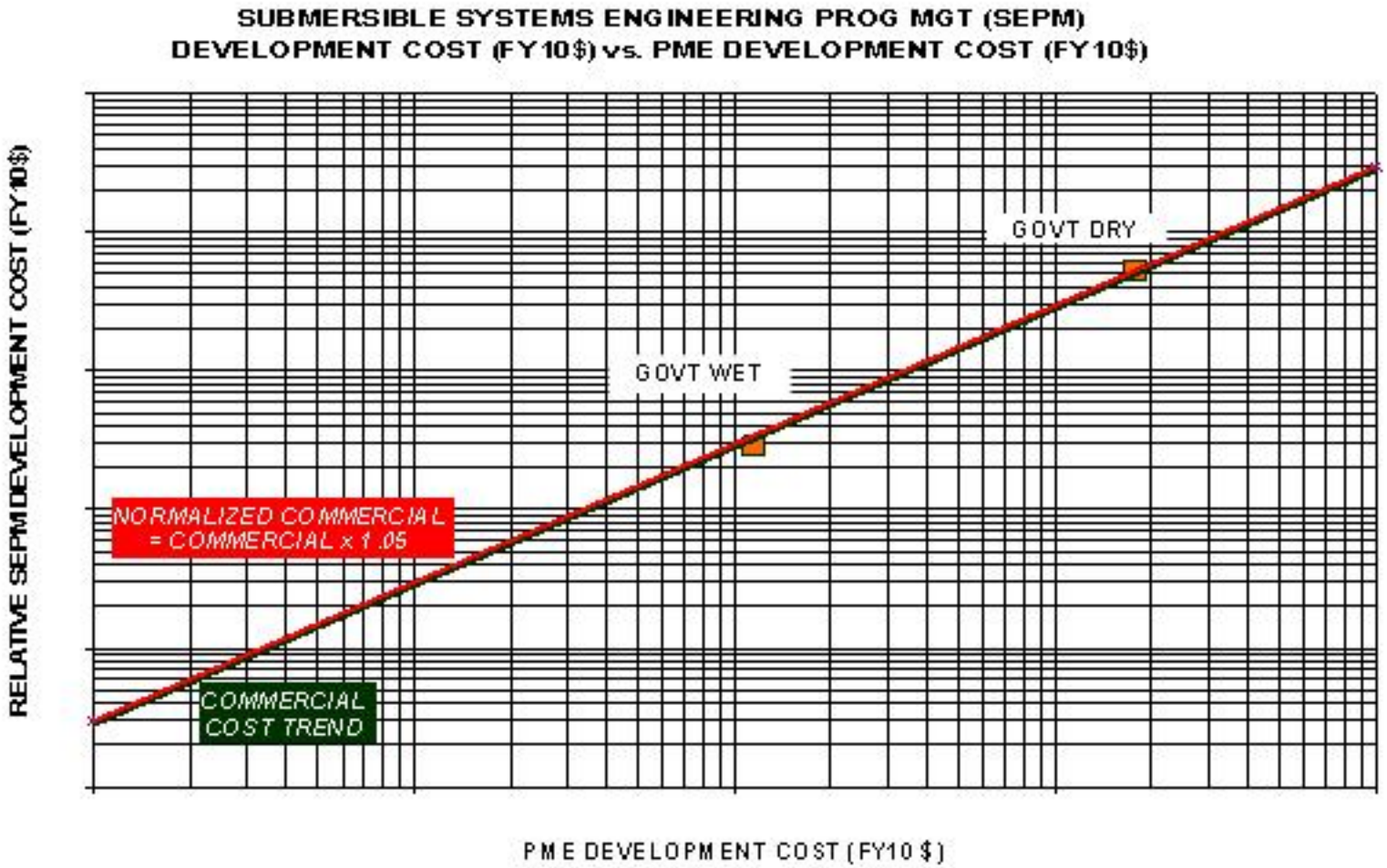
SUBMERSIBLE DEVELOPMENT OTHER COSTS (BTL)



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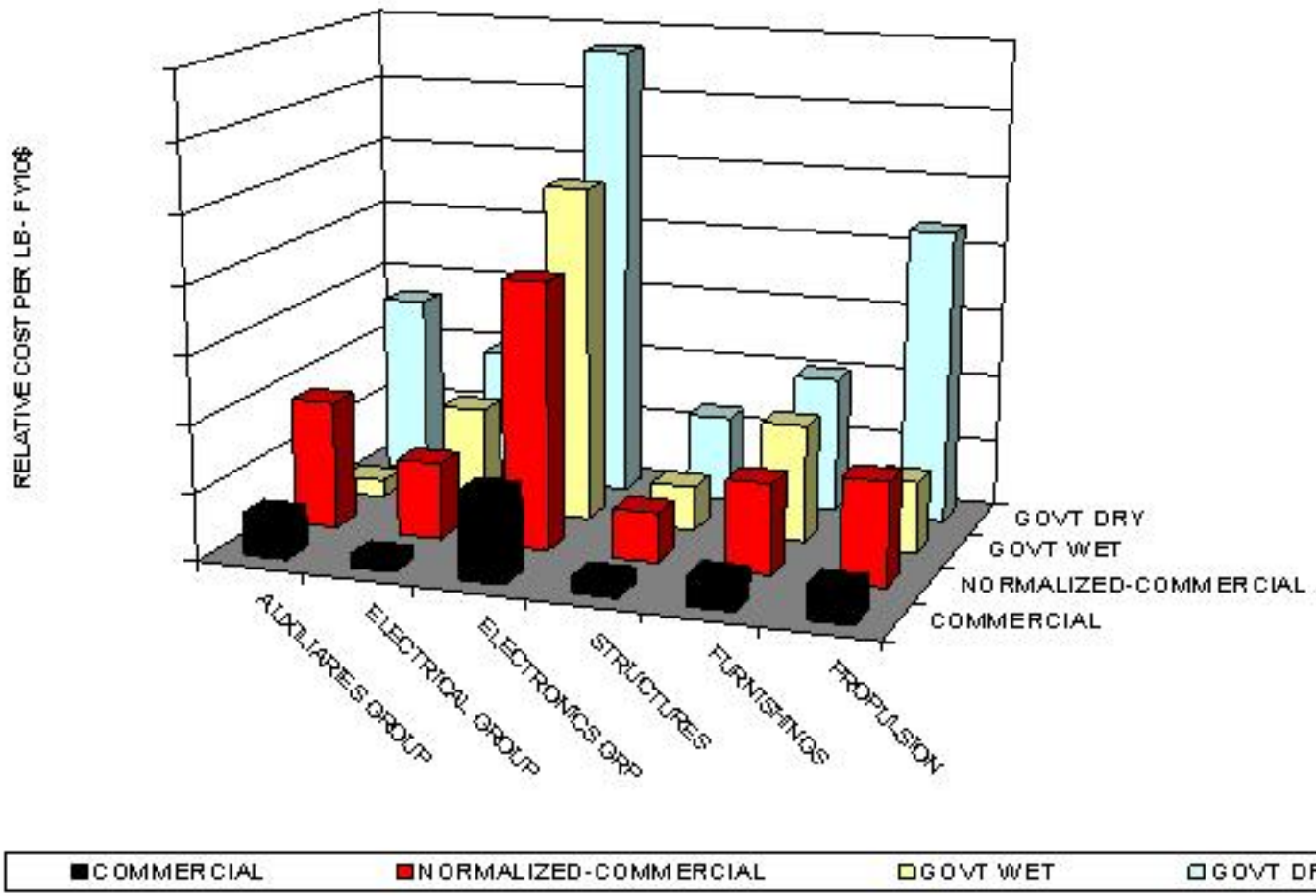
SUBMERSIBLE ENGINEERING DEVELOPMENT MODEL (EDM) COMPONENT SYSTEMS



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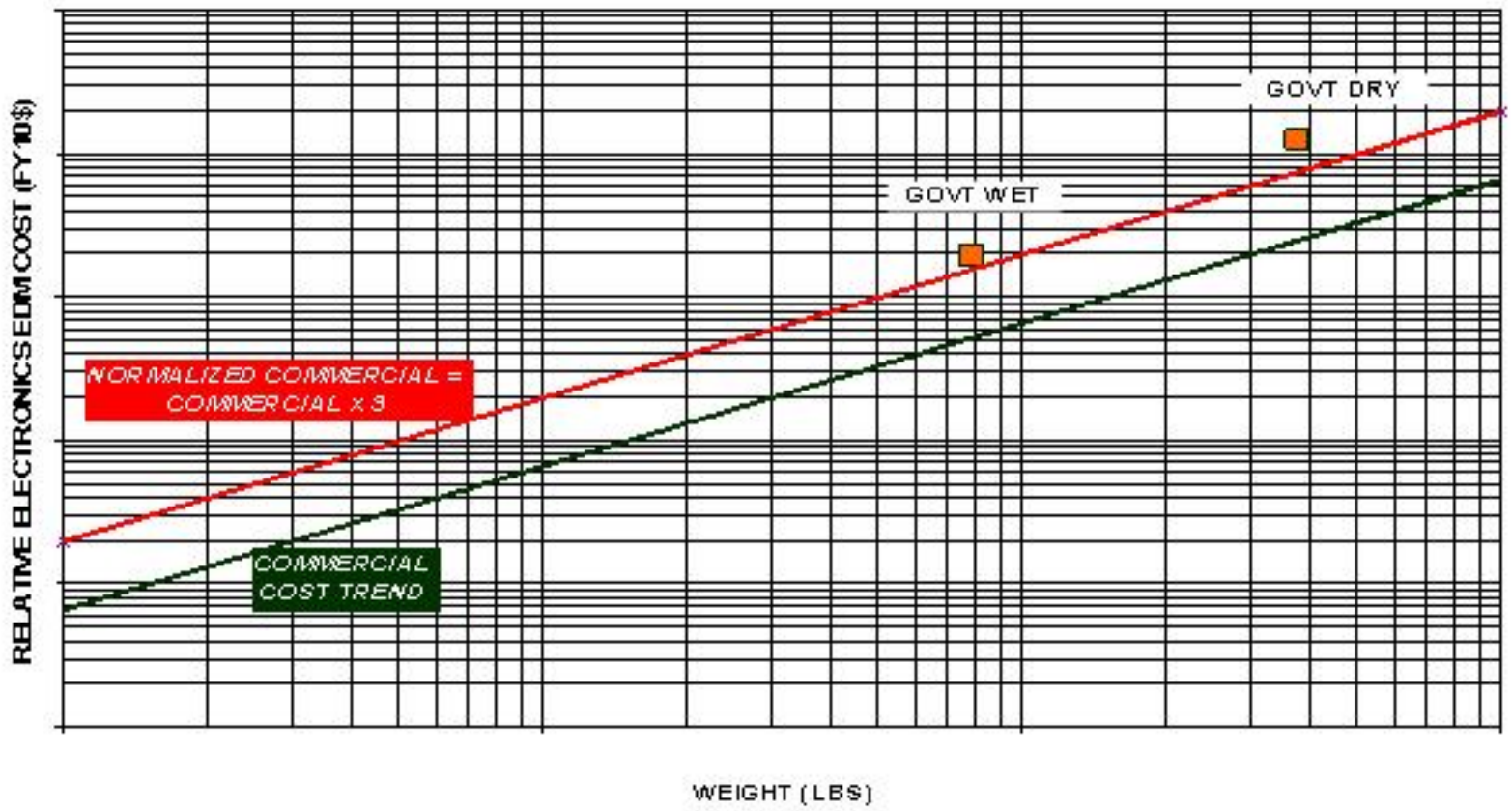
SUBMERSIBLE ENGINEERING DEVELOPMENT MODEL (EDM) COMPONENT SYSTEMS



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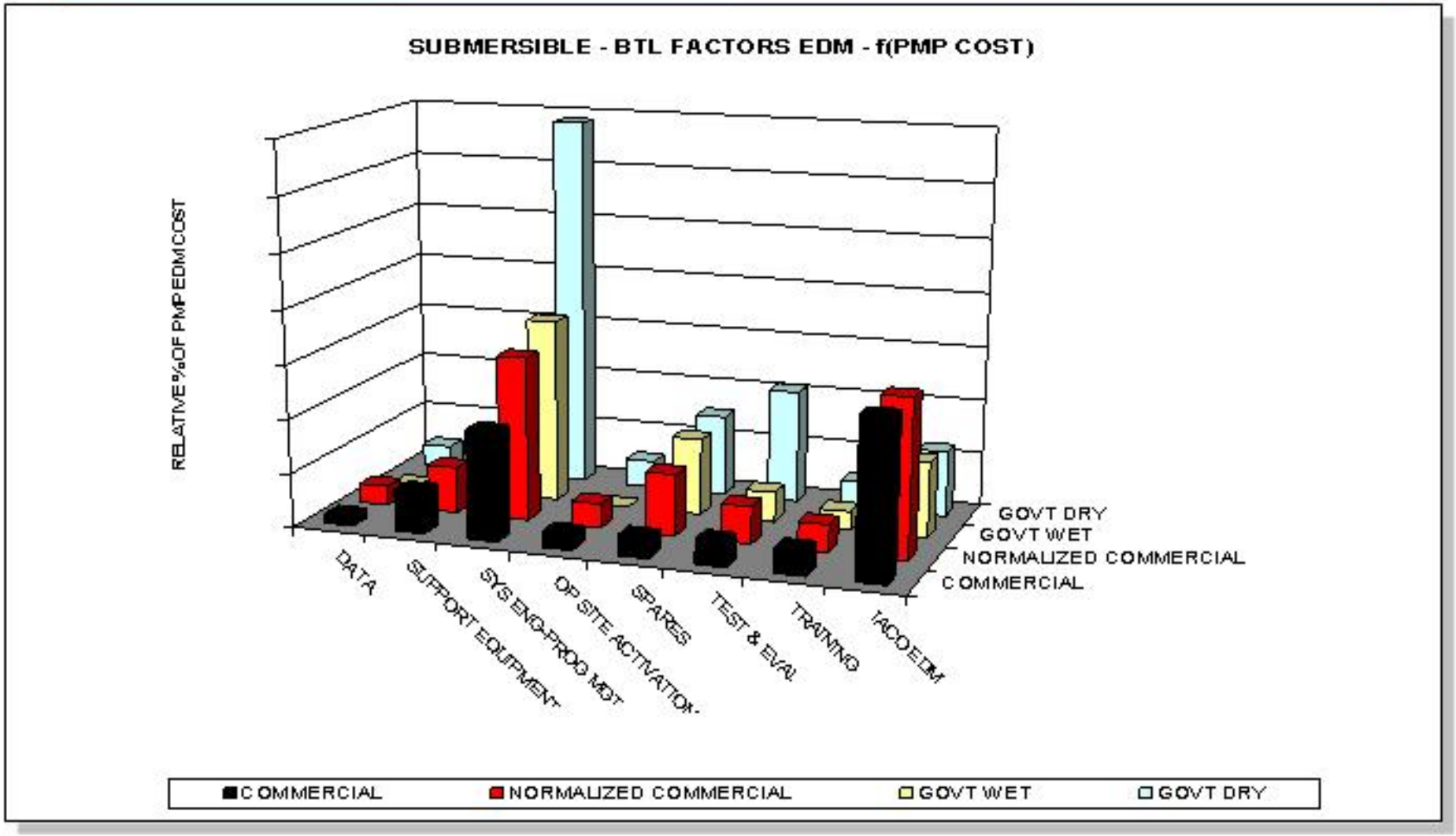
SUBMERSIBLE EDM OTHER COSTS (BTL)



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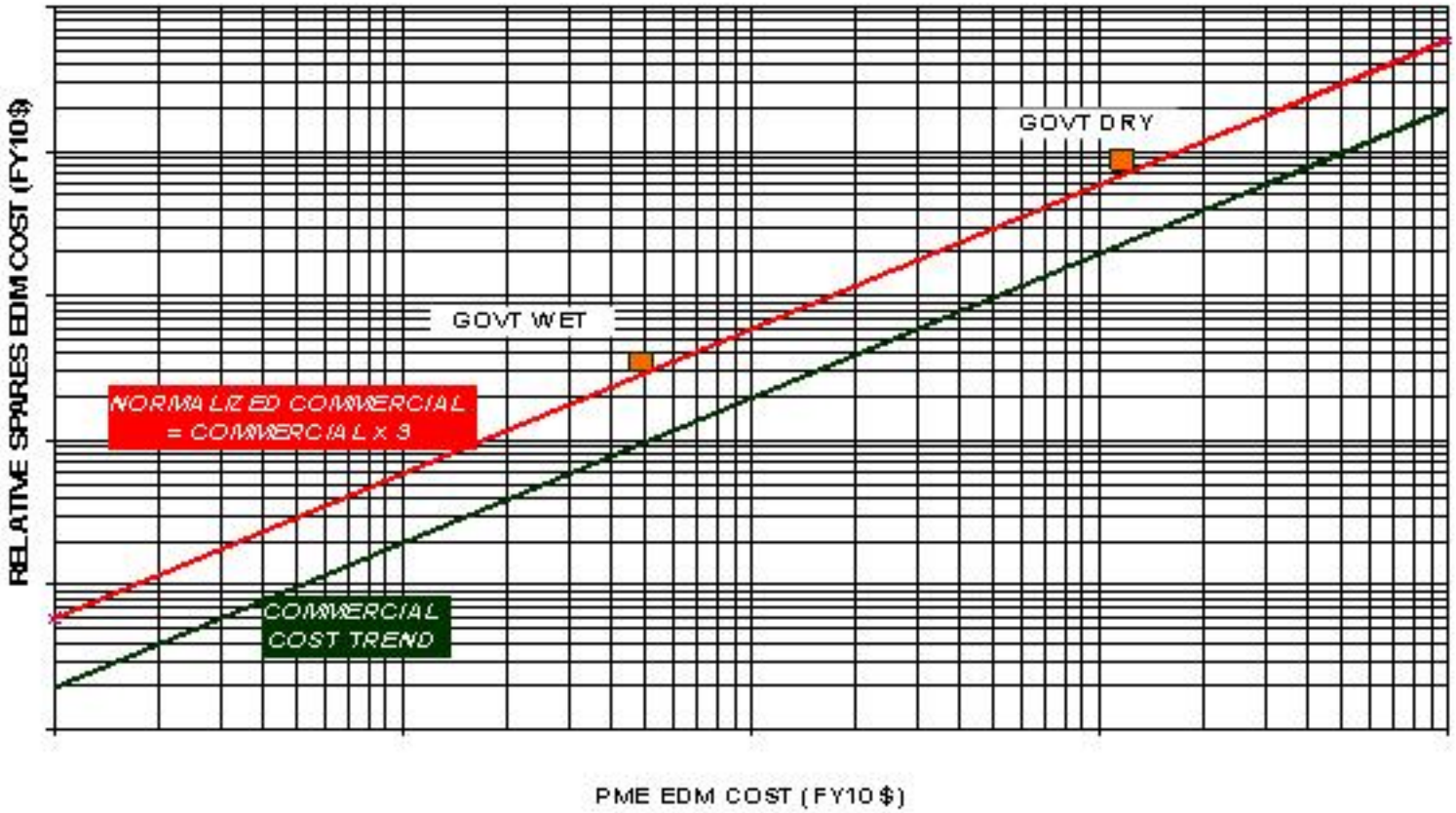
SUBMERSIBLE EDM OTHER COSTS (BTL)



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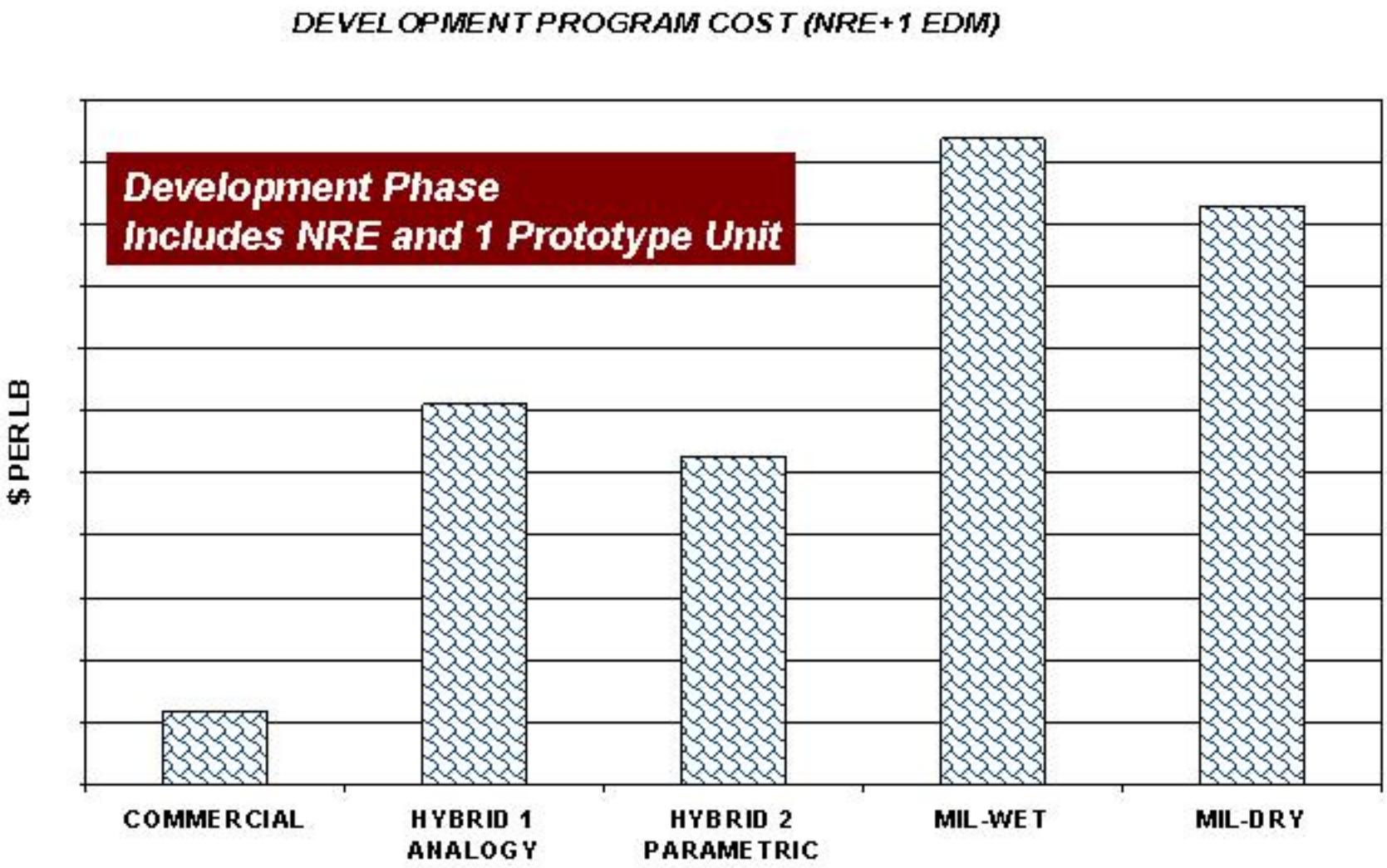
Comparison of Study Outputs – Development Program
Notional 27,000 lb Point Design



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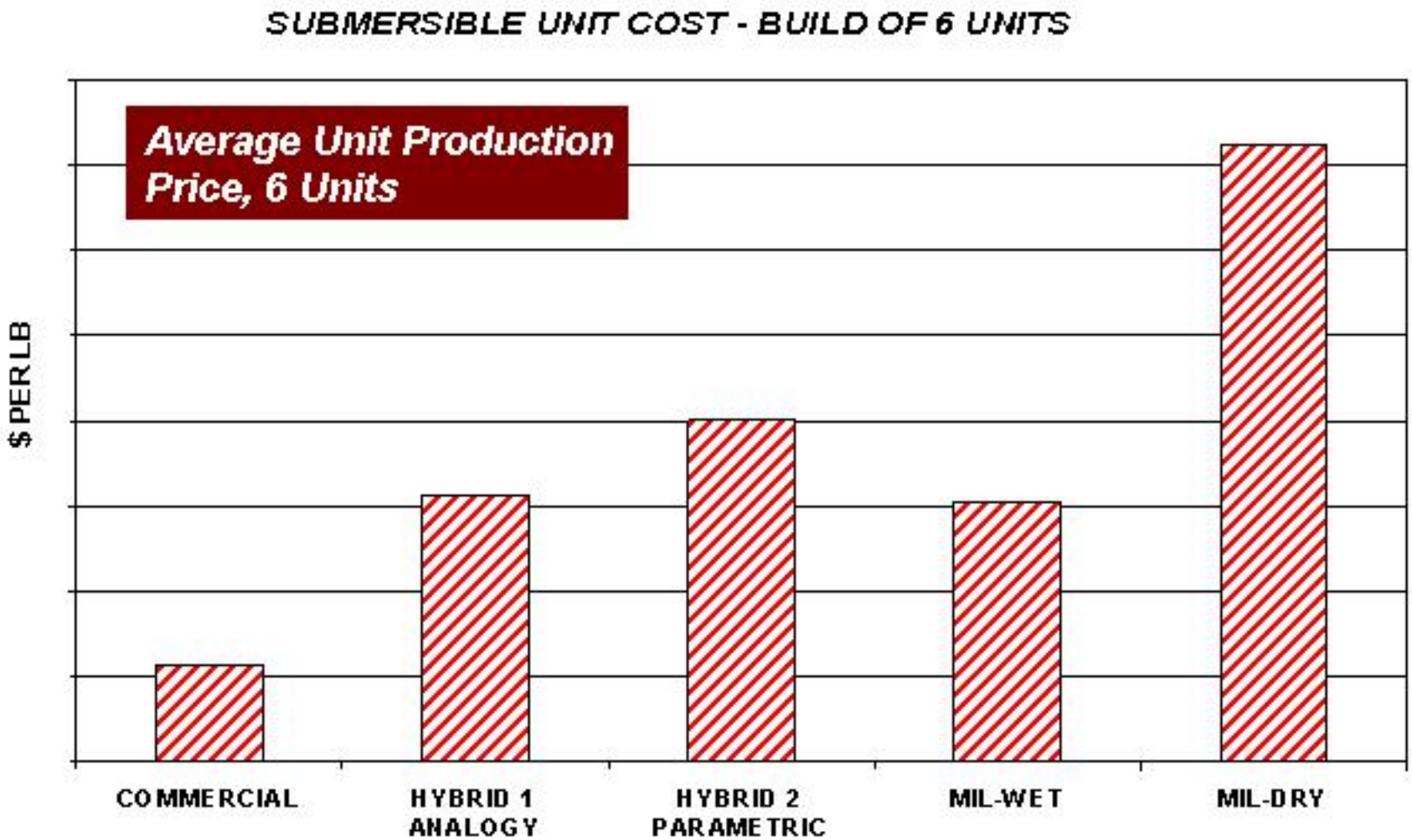
Comparison of Study Outputs – Production Program
Notional 27,000 lb Point Design



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Conclusions - Submersible Program Strategies

- Based upon the size and technical capabilities of the vessel, important cost savings could be captured by the Navy/SOF team by employing commercial suppliers and commercial practices to the greatest extent possible.
- Unfortunately, many commercial practices and industrial conditions are considered to be risky or are unacceptable by the Government. At best, the emerging program will be a "hybrid" with some commercial practices and many "NAVY" mandated practices.
- Quantifying the savings is a problem, because of a lack of robust data for both Government programs and commercial programs. There are many technical and programmatic dissimilarities that require adjustments in cost, but the scale of the adjustments represent opinions based upon very little data.
- There are two basic methods that can be used: an analogy-based approach, with selected interventions and the parametric method. The analogy method offers simplicity, strength, and traceability. The parametric model provides more flexibility where technical characteristics are unsettled or changing.