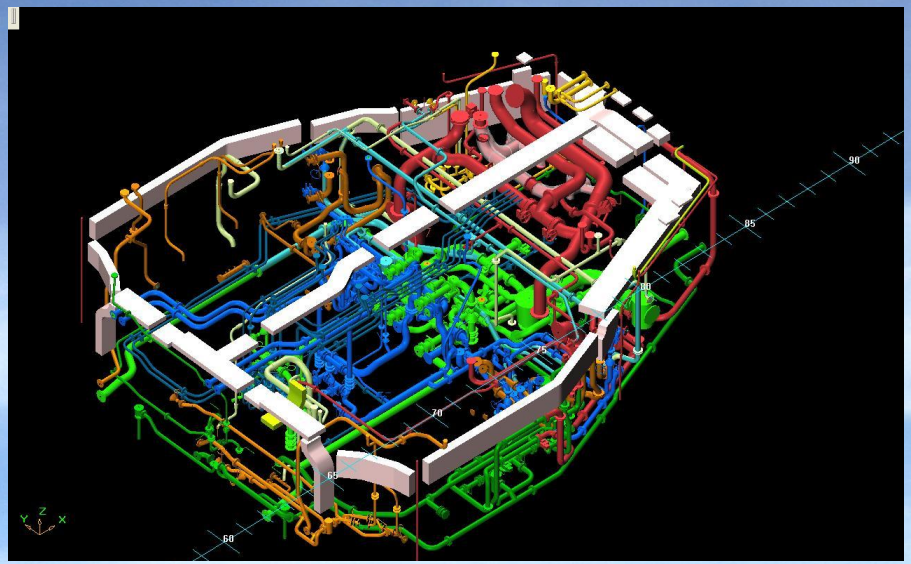
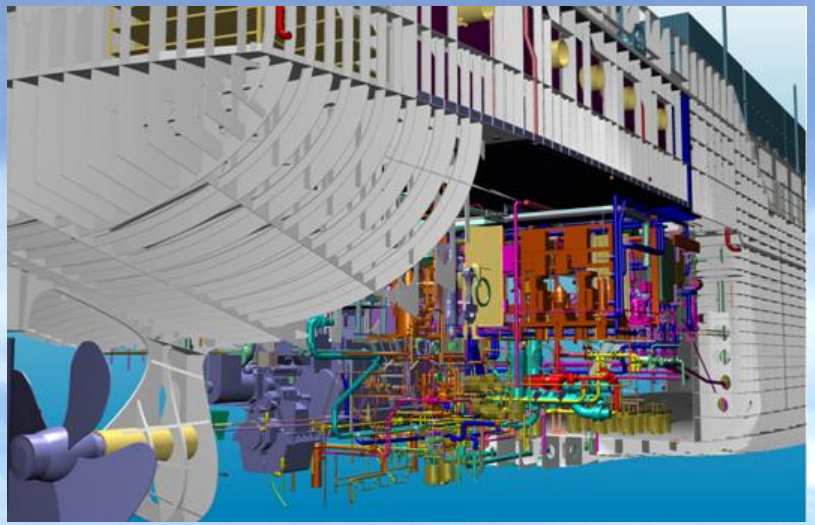
# Estimating Impact of Ship Outfit Density on Production Labor Hours

# Outfit Density

- Outfit density is an indication of how much of a ship's design volume is consumed by machinery, equipment components and the many different outfit systems.
- Highly dense spaces are often too difficult to gain easy access for equipment/system installations, operation, maintenance and potential upgrades.
- Highly dense spaces often require tortured and expensive routings of distributed systems to avoid interferences between competing systems.



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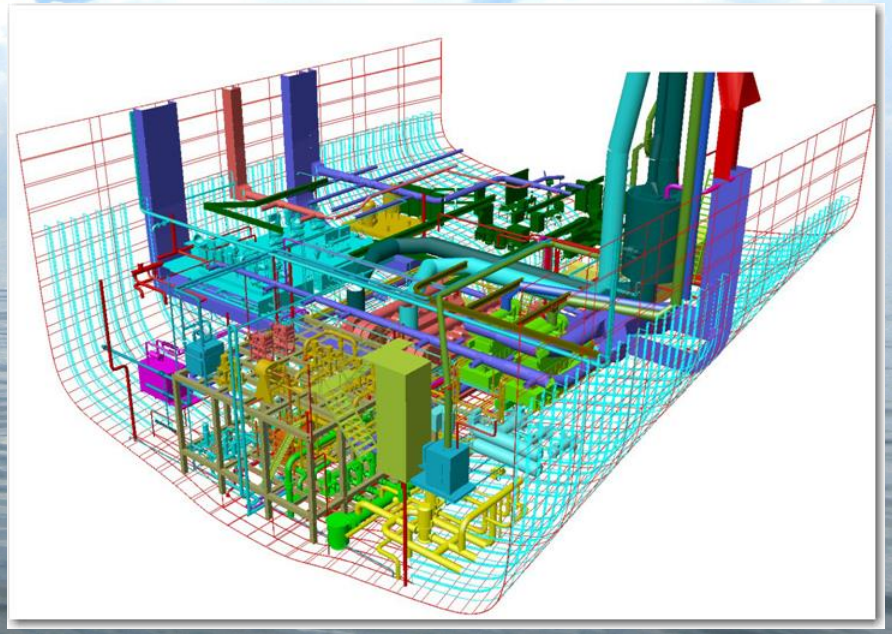


**SPAR has developed cost models that estimate the impact that outfit density has upon new construction and life cycle costs.**

**The development of this methodology had its beginnings during the Navy's PODAC (Production Oriented Design & Construction) Cost Model project from the mid through the end of the 1990's. SPAR was the prime contractor for this effort.**

# What is the PODAC Cost Model?

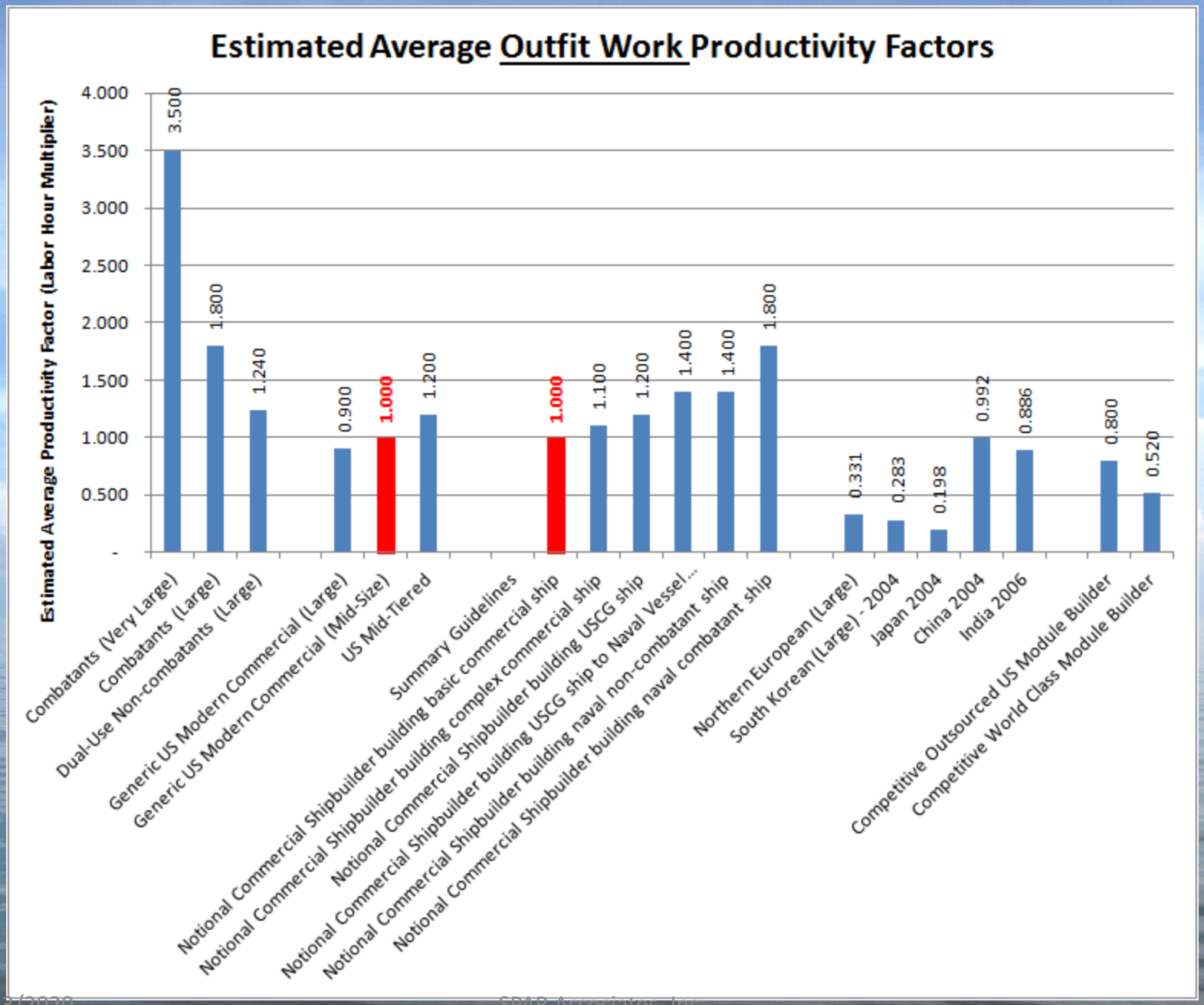
*A Product-Oriented Design and Construction (PODAC) Cost Model is* ***a cost estimating tool*** *that will more accurately* ***reflect the cost of ships*** *being* ***built in modern*** *ship production* ***facilities*** *with* ***modern ship building processes, new architectures, technologies and concepts.***

**Among the many PODAC tasks was a study of relative productivity among U.S. shipbuilders (naval and commercial). This study focused on two primary shipbuilding cost components:**

1. **Labor costs (hours) for fabrication, assembly and construction of structural elements (SWBS 100); and**
2. **Labor costs (hours) for fabrication, assembly and installation of outfit systems (SWBS 200-700).**

**The following chart, largely developed under PODAC, shows average levels of outfit productivity between different types of shipbuilding: naval combatants, naval non-combatants, and commercial.**

**This chart has as its basis the average level of productivity (= 1.00) for performing general commercial grade outfit work by a modern mid-size U.S. shipbuilder that employs reasonably modern production methods of manufacturing and construction.**


Estimated Average Outfit Work Productivity Factors
Estimated Average Productivity Factor (Labor Hour Multiplier)
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
-
3.500
1.800
1.240
0.900
1.000
1.200
1.000
1.100
1.200
1.400
1.400
1.800
0.331
0.283
0.198
0.992
0.886
0.800
0.520
Combatants (Very Large)
Combatants (Large)
Dual-Use Non-combatants (Large)
Generic US Modern Commercial (Large)
Generic US Modern Commercial (Mid-Size)
US Mid-Tiered
Summary Guidelines
Notional Commercial Shipbuilder building basic commercial ship
Notional Commercial Shipbuilder building complex commercial ship
Notional Commercial Shipbuilder building USCG ship
Notional Commercial Shipbuilder building USCG ship to Naval Vessel...
Notional Commercial Shipbuilder building naval non-combatant ship
Notional Commercial Shipbuilder building naval combatant ship
Northern European (Large)
South Korean (Large) - 2004
Japan 2004
China 2004
India 2006
Competitive Outsourced US Module Builder
Competitive World Class Module Builder

**Average productivity levels are shown for other types of ship construction relative to this average commercial productivity.** ***The higher the productivity factor, the greater the labor cost.***

**For example, the PODAC study determined that the average labor cost for outfitting a naval combatant cost 1.8-times that for a commercial grade product.**

**Later, SPAR provided estimates of productivity for other types of shipbuilding, including a comparison of foreign shipbuilders that maximize cost savings from advanced early stage construction methods and improved production engineering.**

# Why Is There Such A Large Labor Cost Variance Between The Different Types Of Ship Construction?

**Cost differentials can be accounted for the following reasons (and others):**

- **Different Design & Engineering Rules (SVR Vs NVR)**
- **Different Levels Of Quality Control & Oversight Requirements**
- **Relative Complexity Of Ship Systems**
- **Quality & Completeness of Detail Engineering for Production**
- **New Materials and/or Production Technologies**
- **Ability To Carefully Plan And Manage Budgets And Schedules**
- **Ship Outfit Density**

# Elements of Ship Construction Costs

| Basic HM&E Systems Costs (Standard Shipbuilding CERs) | + CER Adjustments for Military Requirements<br>• Mil-Spec Material<br>• NVR Requirements<br>• Redundancies<br>• CBRN Requirements<br>• Arctic Service Requirements | + Add Military Systems<br>• Weapons Systems<br>• C4ISR<br>• Special Coatings | X Adjustments for Productivity<br>• Engineering Quality<br>• Commonality<br>• Applied Production Methods & Constr. Stage<br>• Prior Learning<br>• **Outfit Density** | = "Should Cost" |
|---|---|---|---|---|

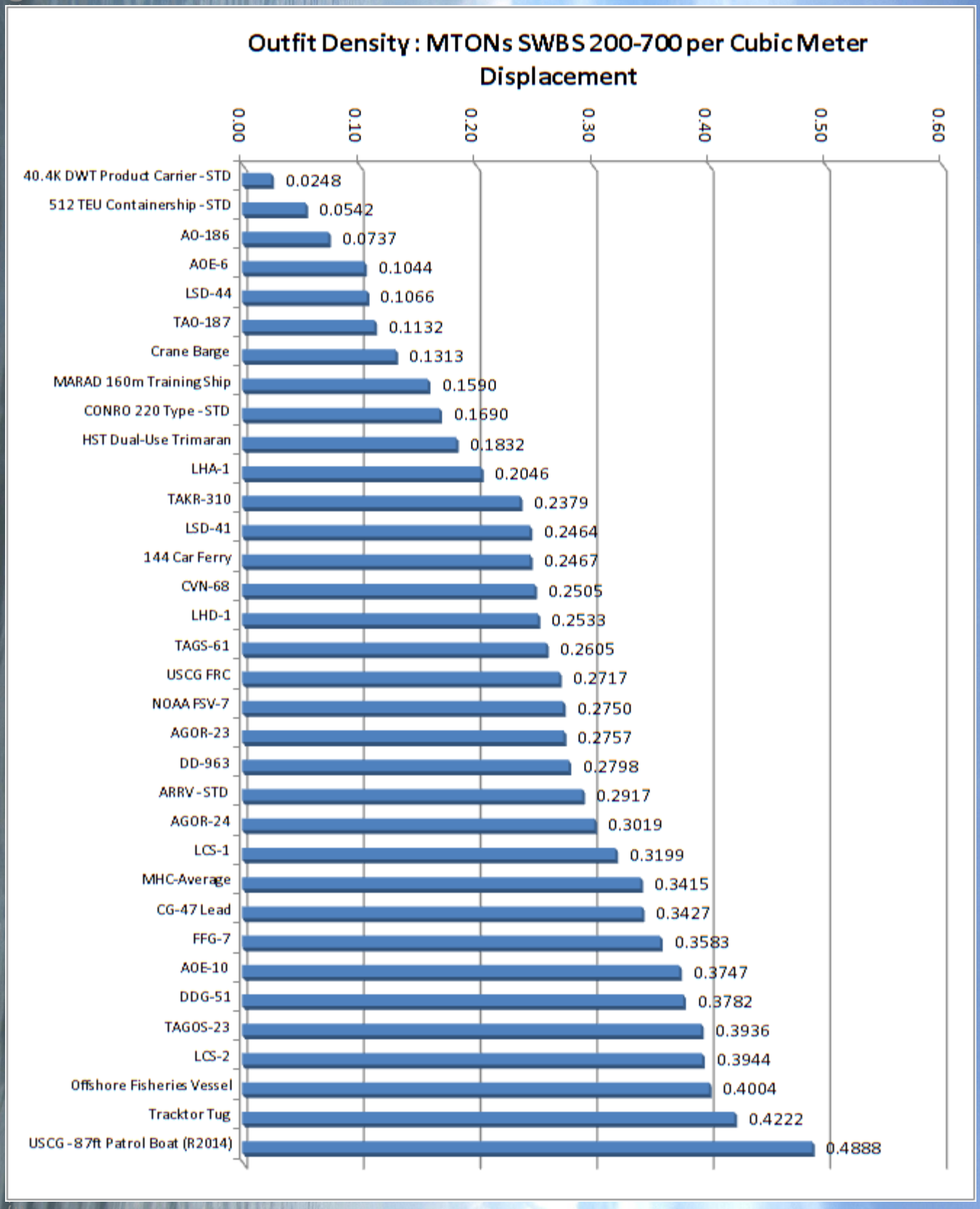
| "Should Cost" | + Cost Risk<br>• Engineering Performance<br>• Production Performance<br>•Management Performance<br>• Potential Impact of Schedule | = "More Likely Cost" |
|---|---|---|

**SPAR developed a method for measuring the impact that ship outfit density has upon construction labor cost. SPAR cost models automatically develop an Outfit Density:**

$$\text{Outfit Density} = \frac{[\Sigma \text{ (weights of SWBS Groups 200-700)}]}{\text{Ship Displacement (m3)}}$$

**This is only a very gross concept for outfit density and does not consider different densities for different areas of the ship.**

**Nevertheless, it has provided a reasonably good measure of adjusting costs when overall outfit density is high.**

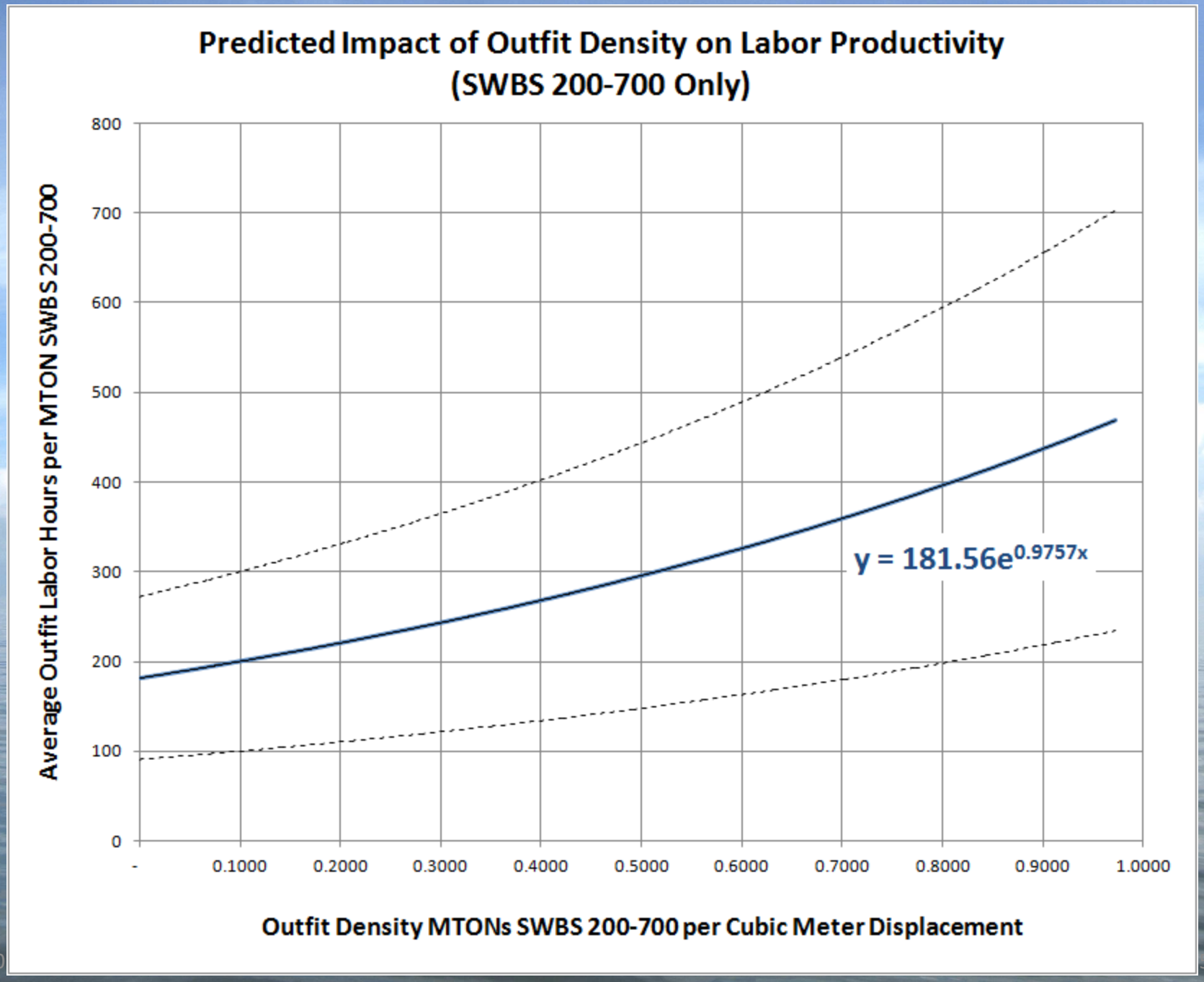

Outfit Density : MTONs SWBS 200-700 per Cubic Meter Displacement
0.00
0.10
0.20
0.30
0.40
0.50
0.60
40.4K DWT Product Carrier - STD
0.0248
512 TEU Containership - STD
0.0542
AO-186
0.0737
AOE-6
0.1044
LSD-44
0.1066
TAO-187
0.1132
Crane Barge
0.1313
MARAD 160m Training Ship
0.1590
CONRO 220 Type - STD
0.1690
HST Dual-Use Trimaran
0.1832
LHA-1
0.2046
TAKR-310
0.2379
LSD-41
0.2464
144 Car Ferry
0.2467
CVN-68
0.2505
LHD-1
0.2533
TAGS-61
0.2605
USCG FRC
0.2717
NOAA FSV-7
0.2750
AGOR-23
0.2757
DD-963
0.2798
ARRV - STD
0.2917
AGOR-24
0.3019
LCS-1
0.3199
MHC-Average
0.3415
CG-47 Lead
0.3427
FFG-7
0.3583
AOE-10
0.3747
DDG-51
0.3782
TAGOS-23
0.3936
LCS-2
0.3944
Offshore Fisheries Vessel
0.4004
Tracktor Tug
0.4222
USCG - 87ft Patrol Boat (R2014)
0.4888

# Developing Effects of Outfit Density Upon Construction Outfit Hours

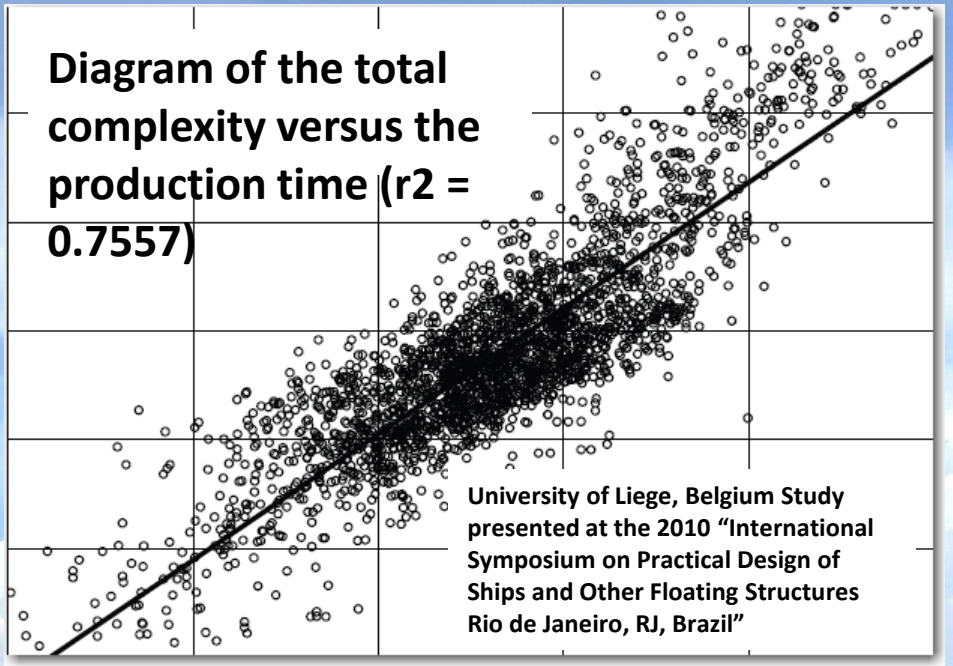
**This outfit density/labor cost study reviewed a very large mix of return costs that involve different degrees of the above listed factors that affect return costs.**

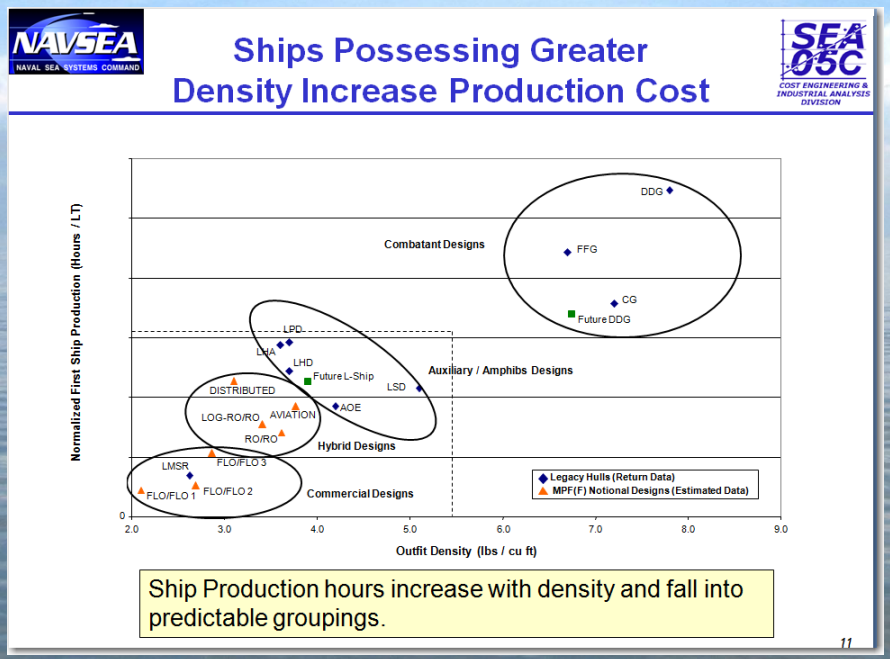
**To correlate labor costs against density, there are a number of factors that need to be taken into consideration. Actual labor costs are dependent on a number of variables:**

1. **Specific Design Rules**
2. **Quality Assurance & Oversight Requirements**
3. **Extent of Early Stage Construction Savings**
4. **Quality & Maturity of Production Planning & Engineering**
5. **Competence & Incisiveness of Informed Management**
6. **Degree Change Orders Affect Budgets & Schedule**
7. **Skills & Discipline of The Work Force**


Predicted Impact of Outfit Density on Labor Productivity
(SWBS 200-700 Only)
Average Outfit Labor Hours per MTON SWBS 200-700
800
700
600
500
400
300
200
100
0
-
0.1000
0.2000
0.3000
0.4000
0.5000
0.6000
0.7000
0.8000
0.9000
1.0000
y = 181.56e0.9757x
Outfit Density MTONs SWBS 200-700 per Cubic Meter Displacement

# Various other studies have come to similar conclusions.

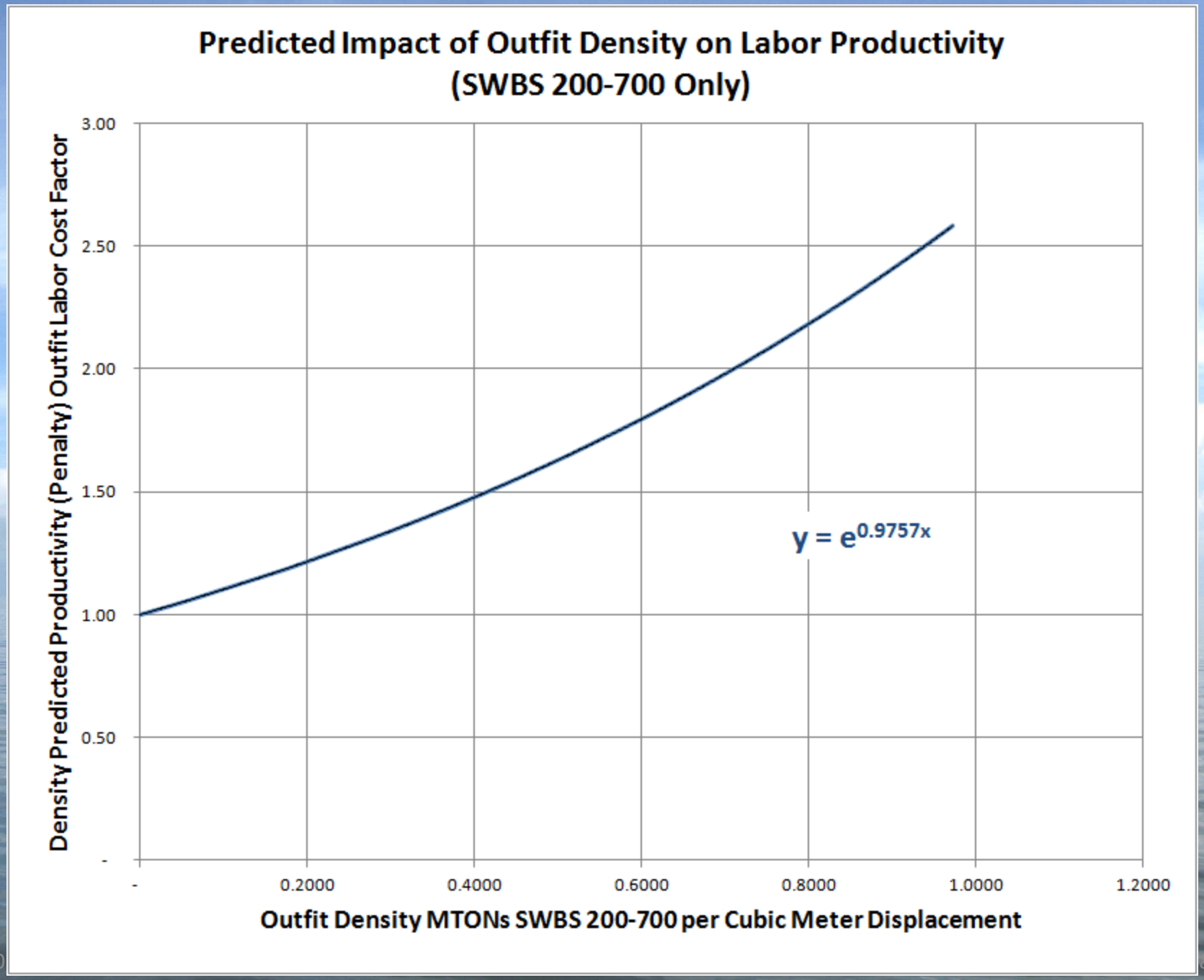


# Developing Outfit Density Labor Hours Productivity/Penalty Factors

**SPAR has developed a variety of estimating cost models that offer a large selection of costs for various shipbuilding systems and services. These costs have been compiled from actual shipbuilding costs, but adjusted to reflect those labor costs normally associated with a notional U.S. mid-size shipyard building relatively simple commercial ship types.**

**These cost model costs (Cost Estimating Relationships, or CERs) are adjusted using an Productivity/Penalty Factor, which is a direct formulation of the Outfit Hours per Total Outfit Weight (SWBS 200-700) shown above.**


Predicted Impact of Outfit Density on Labor Productivity
(SWBS 200-700 Only)
Density Predicted Productivity (Penalty) Outfit Labor Cost Factor
3.00
2.50
2.00
1.50
1.00
0.50
-
y = e^0.9757x
-
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
Outfit Density MTONs SWBS 200-700 per Cubic Meter Displacement

**The Productivity/Penalty Factor is a formula that adjusts the Average Labor Hours per Total Outfit (SWBS 200-700) Weight so that it starts at 1.00 when the Outfit Density equals 0.0. This corresponds to work performed on the least dense commercial (ABS Steel Vessel Rules, "SVR" design or equivalent) ship type.**

**The Penalty Factor then increases with the increase in outfit density as shown in the preceding chart.**

**The following slide shows where the Outfit Density and the Outfit Labor Cost Penalty Factor are used in the SPAR cost model.**

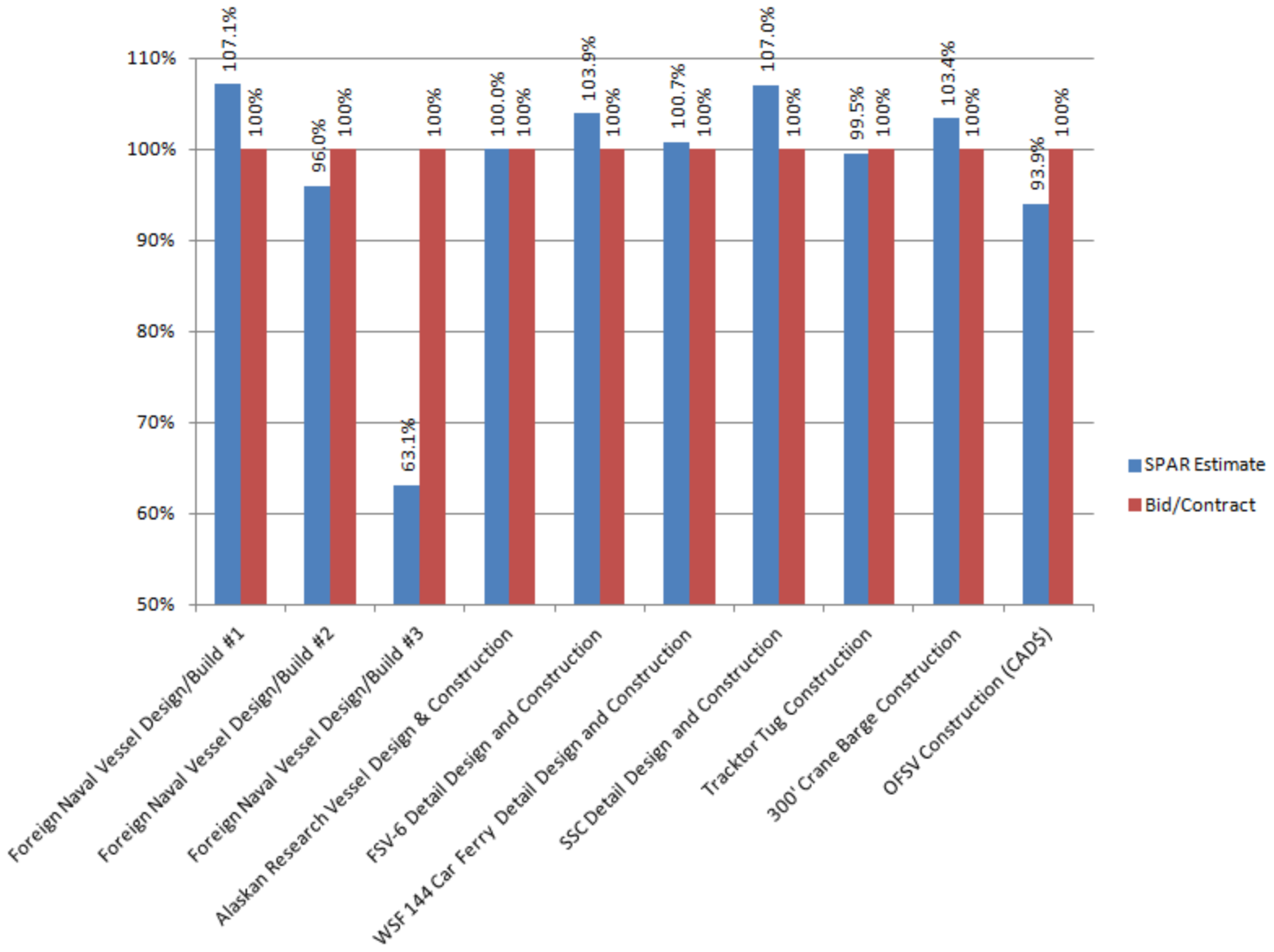
# How Effective is the Productivity/Penalty Factor For Improving a Cost Estimate?

**SPAR has been successfully providing independent cost estimates for approximately 20 years.**

**A good measure of a successful estimate is whether or not it closely matches the ultimate bid or the value of the contract award.**

**The following chart compares a selection of SPAR estimates against bids and contract awards over the past 5 years. These estimates are based upon SPAR's estimated "Should Costs" plus whatever Cost Risk is generated by the cost model for the ship design being estimated. They do not reflect any subsequent changes to these contracts.**

# Comparing SPAR Estimate with Bid/Contract Price (Over Last 5 Years)



# Serving the Ship Design, Building & Repair Industries for Over 45 Years