

Analysis of the Impact of OPTEMPO on Navy O&S Cost

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Prepared for:
Department of Defense Cost Analysis Symposium
13 February 2004

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Outline

- **Battle Group Deployment Analysis**
 - Air Component Analysis
 - Ship Component Analysis
- **Total Fleet Level Analysis**

COST OF BATTLE GROUP DEPLOYMENTS

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Objective

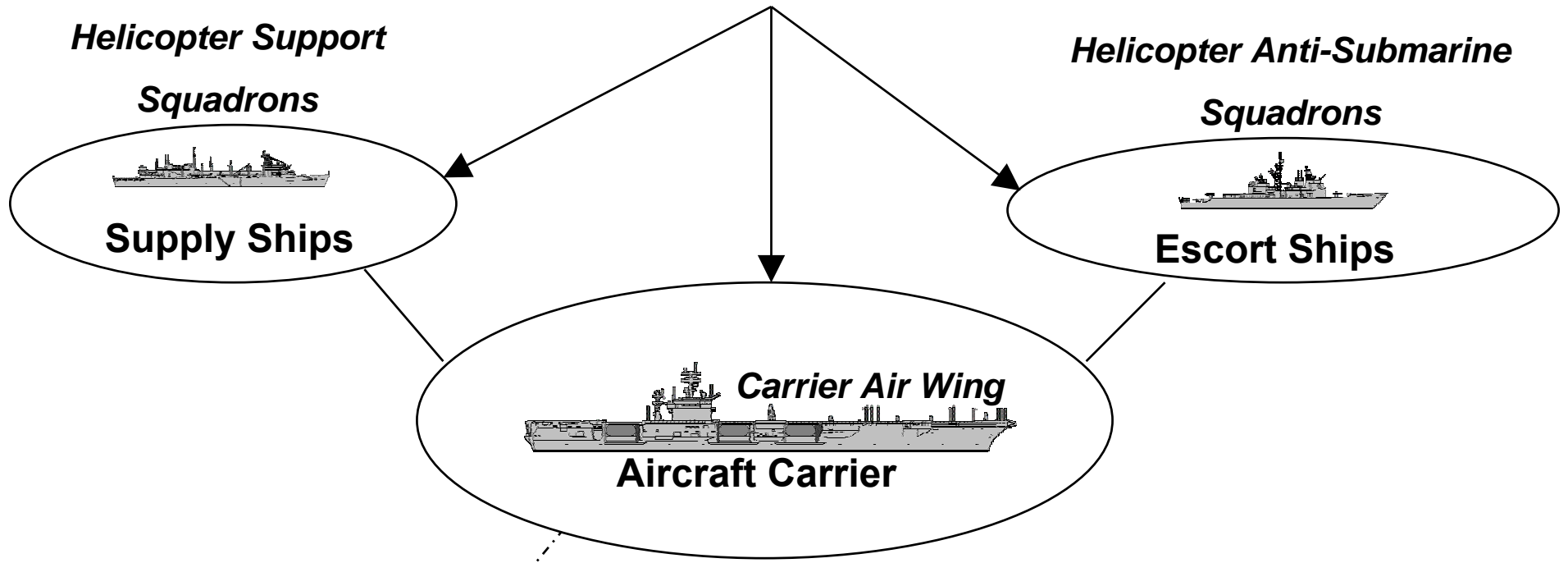
- Develop an approach to estimate the costs associated with overseas Naval carrier battle group deployments of varying complexity using VAMOSC data
- Answer the questions:
 - What is the cost to deploy a carrier air wing?
 - What is the cost to deploy a carrier battle group?
 - How does deployment cost relate to operation type and location?
- Develop a better understanding of the effects of OPTEMPO on the cost of operations

Outline

- Carrier Battle Group Deployments 101
- Carrier Battle Group Air Wing Analysis
- Carrier Battle Group Ship Analysis
- Conclusions

Carrier Battle Group (CVBG) Components

Components in this analysis



Amphibious Assault Aircraft



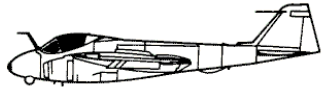
Amphibious Readiness Group

- **Analysis of CVBG Ships**
- **Analysis of Carrier Air Wing**

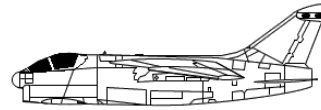
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Carrier Air Wing Composition

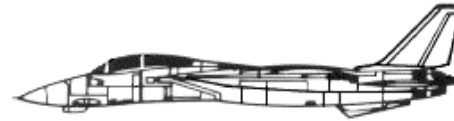
Fighter/Attack Aircraft – average of 46 per air wing, range = 32 to 54



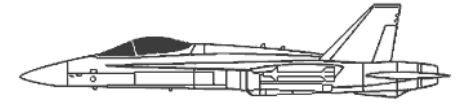
A-6 (thru 1997)



A-7 (thru 1991)



F-14

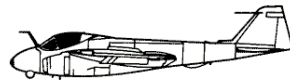


F/A-18

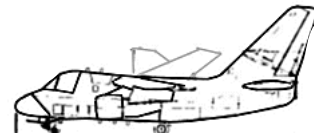
Support Aircraft – average of 24 per air wing, range = 16 to 27



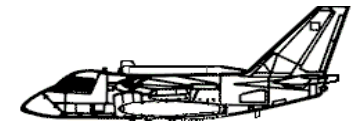
EA-6



KA-6



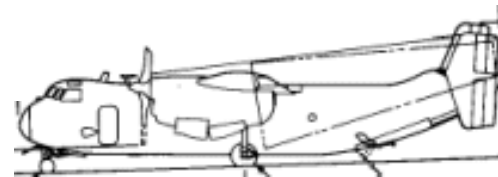
S-3



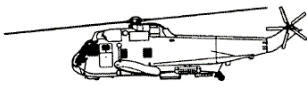
ES-3 (1993 thru 1998)



E-2



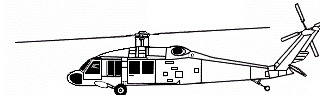
C-2



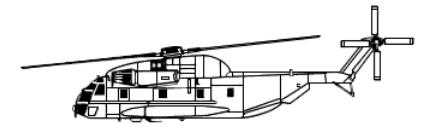
SH-3 (thru 1994)



SH-60



HH-60



CH-53

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Battle Group Deployments

- Approximately 70 battle groups spanning 18 separate carriers have been deployed overseas since the start of FY90
 - Approximately half are Western Pacific deployments (departing from the West coast of the U.S.) and half are Mediterranean deployments (departing from the East coast of the U.S.)
 - PACFLT battle groups engage in operations between the Persian Gulf and the U.S. west coast
 - LANTFLT battle groups engage in operations between the Persian Gulf and the U.S. east coast
- All deployments are six months in duration (+/- 2 weeks)
- Battle groups are typically engaged in more than one operation during a deployment period
- Battle groups vary in their composition of ships and aircraft

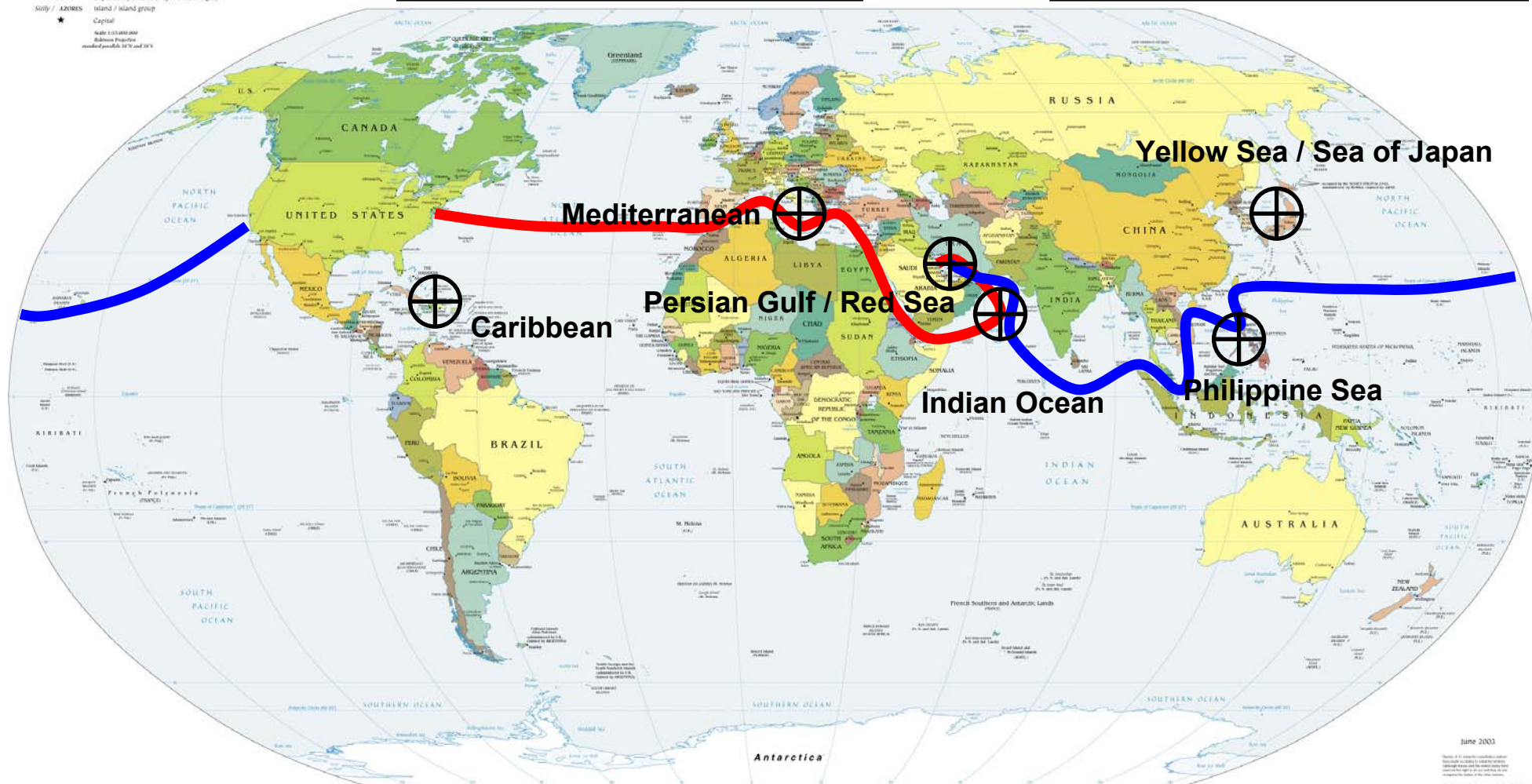
Typical Battle Group Deployments

Political Map of the World, June 2003

AUSTRALIA
Bermuda
Sully / AZORES
★
independent state
Dependency or area of special sovereignty
Island / island group
Capital
Scale 1:10,000,000
Reference Projections
modified WGS84, UTM and UTM

“MED” Deployments

“PAC” Deployments



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Naval Operations in Iraq



| OPERATION | YEAR(S) | TYPE |
|----------------------|-------------|---------------------|
| Desert Shield | 1990 | Show of Force |
| Imminent Thunder | 1990 | Show of Force |
| Desert Storm | 1991 | Major Combat |
| Provide Comfort | 1991-1996 | Show of Force |
| Southern Watch | 1992-2003 | No Fly Zone |
| Vigilant Warrior | 1994 | Show of Force |
| Vigilant Sentinel | 1995-1996 | Show of Force |
| Desert Strike | 1996 | Strike |
| Desert Thunder | 1997-1998 | Show of Force |
| Desert Fox | 1998 | Strike |
| Iraqi Freedom | 2003 | Major Combat |

Approximate Sortie Distances:

Persian Gulf: 500 miles
Red Sea: 1200 miles

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Naval Operations in Afghanistan



| OPERATION | YEAR(S) | TYPE |
|------------------|----------------|--------------|
| Infinite Reach | 1998 | Strike |
| Enduring Freedom | 2001 – present | Major Combat |
| Anaconda | 2002 | Major Combat |

Approximate Sortie Distances: 1500 miles

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Naval Operations in Bosnia



| OPERATION | YEAR(S) | TYPE |
|-------------------------|--------------|---------------------|
| Provide Promise | 1992–1996 | Humanitarian |
| Sharp Guard | 1992-1996 | Show of Force |
| Deny Flight | 1993-1995 | No Fly Zone |
| Deliberate Force | 1995 | Major Combat |
| Decisive Edge | 1996 | No Fly Zone |
| Deliberate Guard | 1996-1998 | No Fly Zone |
| Deliberate Forge | 1998-present | No Fly Zone |
| Allied Force | 1999 | Major Combat |

Approximate Sortie Distances:

100 miles

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Carrier Air Wing (CVW) Analysis

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Hypotheses

1. The cost of CVW operations is dependent on the OPTEMPO of the CVW
 - CVW OPTEMPO can be measured in terms of the number of flight hours and sorties flown on a deployment

2. Flight hours and sorties are dependent on the type of operation engaged and the geographical location of the operation
 - A. Geographical location of the operation has a strong influence on flight hours per sortie
 - B. Operation type has a strong influence on the total number of air wing sorties flown

Approach

- Develop two databases
 - Cost Database
 - Deployment Database
- Analyze the cost database to prove hypothesis 1
- Analyze the deployment database to prove hypotheses 2A and 2B

Building the Cost Database

- Develop a database consisting of:
 - VAMOSC direct operations cost data by Type-Model-Series (TMS) for carrier based aircraft by year
 - » Direct Operations Data = Regular Aircraft Organizational and Intermediate Costs
 - Regular aircraft count and flight hours by TMS by year
 - Sorties by TMS by year
 - » Sortie data accumulated using the Equipment Condition Analysis (ECA) system
- Resulting database consisted of 187 data points

Building the Deployment Database

- Identify dates, durations, and locations of all carrier battle group deployments from 1990 to 2002
 - Deployments must begin and end within a Fiscal Year to remain compatible with VAMOS data
- For the resulting set of deployments, identify the following:
 - General Information
 - » Names, dates, and locations of operations engaged
 - » Dates and locations of port visits
 - Aircraft Data
 - » Squadrons and the TMS aircraft operated by each squadron
 - » Tail Numbers of the aircraft within the squadrons
 - » Flight Hours and sorties by tail number
 - Ship Data
 - » Hull numbers within the battle group
 - » Steaming hours expended
 - » Rate of barrels of fuel expended per steaming hour

Sources of Deployment Data

- Data was assembled from a variety of sources, including the following:
 - Naval Historical Center
 - » Commander Carrier Group Reports
 - Identifies dates, durations, and locations of deployments and operational engagements
 - Identifies carrier air wing squadrons deployed
 - » Naval Aviation News Articles
 - Naval Air Systems Command
 - » Aircraft Inventory and Readiness Reporting System (AIRRS)
 - Identifies tail numbers of aircraft by squadron by date
 - » Equipment Condition Analysis (ECA)
 - Identifies flight hours and sorties by tail number by date
 - Center for Naval Analysis (CNA)
 - » Various data and analyses pertaining to historical Naval operations
 - GlobalSecurity.org
 - » Ship, squadron, and operation summaries

Resulting Deployment Database

- 35 separate carrier battle group deployments
 - 35 deployments represents approximately half of all carrier battle group deployments between 1990 and 2002
 - The data includes a mix of Mediterranean and Western Pacific deployments
 - » Several forward deployed carrier battle groups are included in the data
 - The data spans across battle groups based on 15 different aircraft carriers, from CV-41 (Midway), to CVN-75 (Truman)
 - For each carrier battle group deployment, as few as one named operation is engaged by the battle group, to as many as six

Analysis Results - Hypothesis 1

CVW Direct Operations \$ (FY03\$) =

$$\left(\frac{\text{AVG \$}}{\text{AC}} \right) \times \left(\frac{\text{HPS}}{\text{AVG HPS}} \right)^{0.53} \times \left(\frac{\text{SPA}}{\text{AVG SPA}} \right)^{0.19} \times \left(\frac{\text{AC}}{\text{AVG AC}} \right)^{1.18} \times \left(\text{AC} \right)$$

Variable Definitions:

AC = Count of Aircraft
 HPS = Hours per Sortie
 SPA = Sorties per Aircraft

Applicable data ranges:

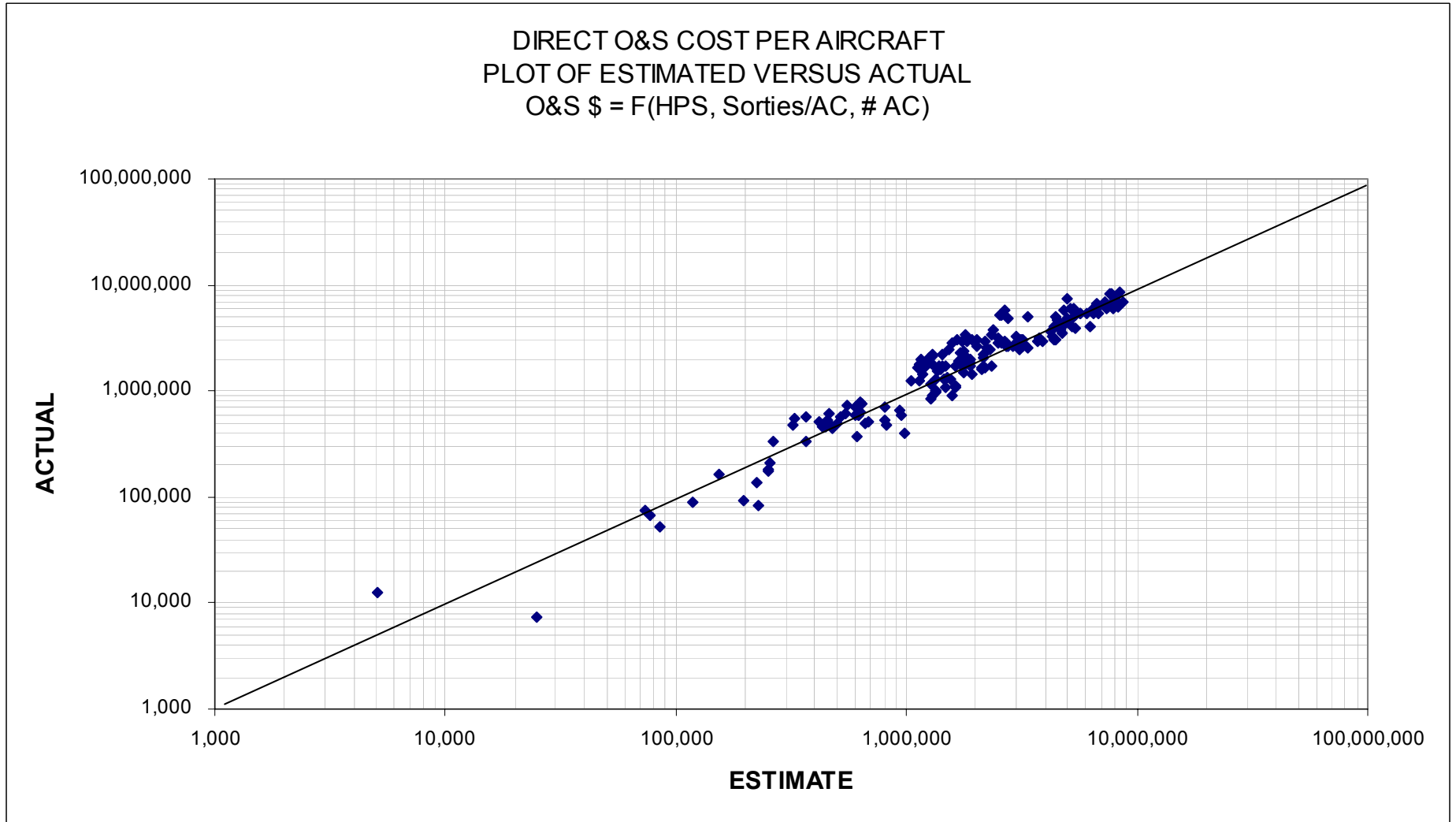
1 ≤ AC ≤ 361
 1.32 ≤ HPS ≤ 3.05
 7 ≤ SPA ≤ 369

Statistics:

| Coefficient | T-Stat | Sig |
|-------------|--------|------|
| Intercept | 551.9 | 100% |
| HPS | 4.5 | 100% |
| SPA | 2.5 | 99% |
| AC | 40.6 | 100% |

| | |
|-----------|-------|
| R-Squared | 92.7% |
| F-Stat | 780.2 |
| DOF | 183 |

Analysis Results - Hypothesis 1



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Analysis Results - Hypothesis 2A

Flight Hours per Sortie (HPS) =

$$\left(\text{AVG HPS} \right) \left(\frac{\text{FR}}{\text{AVG FR}} \right)^{-0.14} \left(e^{(0.08 * \text{PW})} \right) \left(e^{(0.16 * \text{RW})} \right) \left(e^{(-0.10 * \text{IOTW})} \right) \left(e^{(0.16 * \text{AW})} \right) \left(e^{(-0.06 * \text{BOTW})} \right) \left(e^{(0.12 * \text{SOM})} \right)$$

Variable Definitions:

HPS = Hours per Sortie

FR = Ratio of Fighter/Attack Aircraft Count to Support Aircraft Count

Primary Operation Location / Type Variables (value = 1 if the condition applies):

PW = War with Iraq, based in the Persian Gulf

RW = War with Iraq, based in the Red Sea

IOTW = Iraq operations other than war

AW = War with Afghanistan

BOTW = Bosnia operations other than war

SOM = Somalia operations

Note: The status quo (i.e., all location / type variables = 0) corresponds to war with Bosnia

Analysis Results - Hypothesis 2A

Applicable data ranges:

$$1.33 \leq \text{HPS} \leq 2.94$$

All other variables are “dummy” type variables (enter 1 if the variable type applies, enter 0 if it doesn't apply)

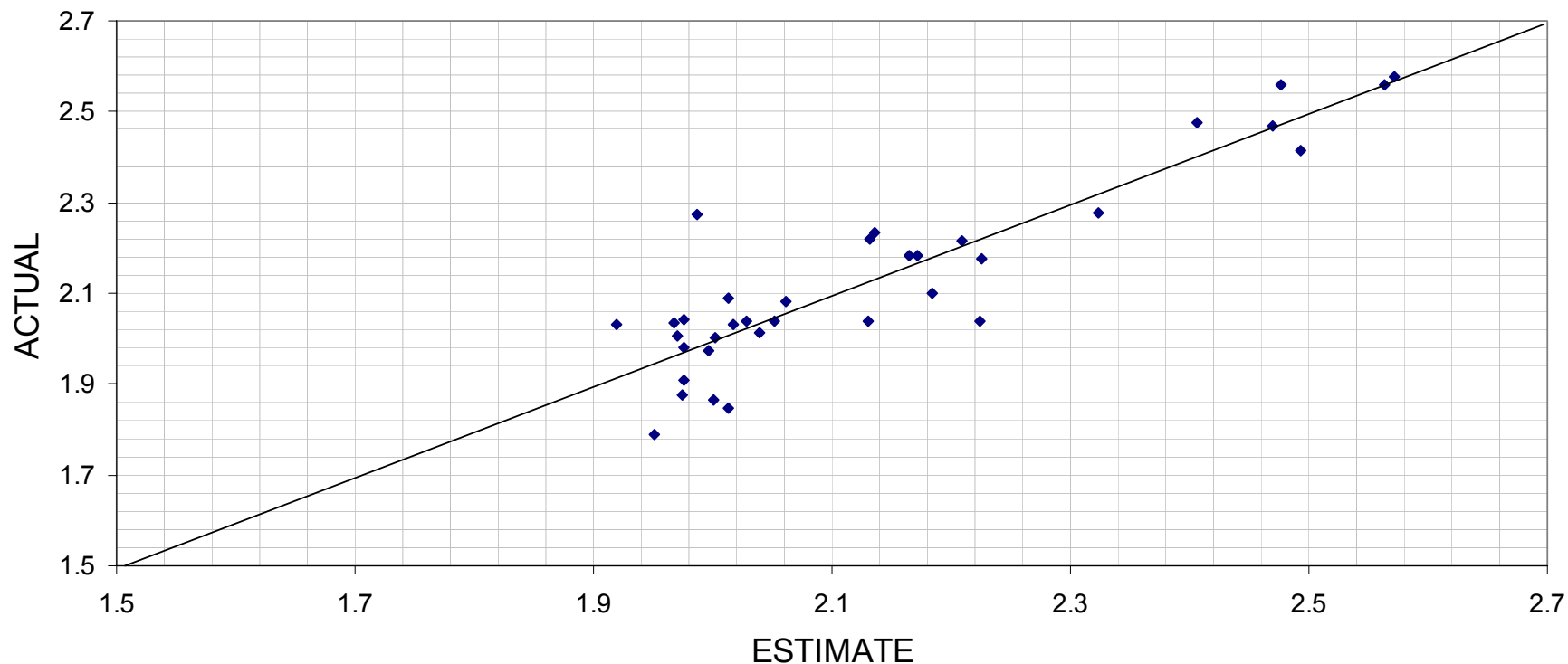
Statistics:

| Coefficient | T-Stat | Sig |
|-------------|--------|------|
| Intercept | 36.8 | 100% |
| FR | 2.4 | 97% |
| PW | 3.3 | 99% |
| RW | 3.7 | 100% |
| IOTW | 4.4 | 100% |
| AW | 3.8 | 100% |
| BOTW | 2.1 | 95% |
| SOM | 2.2 | 96% |

| | |
|-----------|-------|
| R-Squared | 79.4% |
| F-Stat | 14.8 |
| DOF | 27 |

Analysis Results - Hypothesis 2A

FLIGHT HOURS PER SORTIE
PLOT OF ESTIMATED VERSUS ACTUAL
 $HPS = F(\text{FIGHTER/ATTACK RATIO}, \text{DEPLOYMENT LOCATION})$



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Analysis Results - Hypothesis 2B

TOTAL CVW DEPLOYED SORTIES =

$$\left(\frac{\text{AVG TDS}}{\text{TDS}} \right) \times \left(\frac{\text{DD}}{\text{AVG DD}} \right)^{0.92} \times \left(\frac{\text{AC}}{\text{AVG AC}} \right)^{0.53} \times \left(\frac{\text{FR}}{\text{AVG FR}} \right)^{0.29} \times \left(e^{(0.12 * \text{MC})} \right)$$

Variable Definitions:

TDS = Total Deployed Sorties

DD = Number of days deployed

AC = Number of aircraft deployed

FR = Ratio of Fighter/Attack Aircraft Count to Support Aircraft Count

MC = Major Combat

Analysis Results - Hypothesis 2B

Applicable data ranges:

| | | | | |
|-----|---|----|---|-----|
| 112 | ≤ | DD | ≤ | 198 |
| 56 | ≤ | AC | ≤ | 79 |
| 1.3 | ≤ | FR | ≤ | 2.9 |

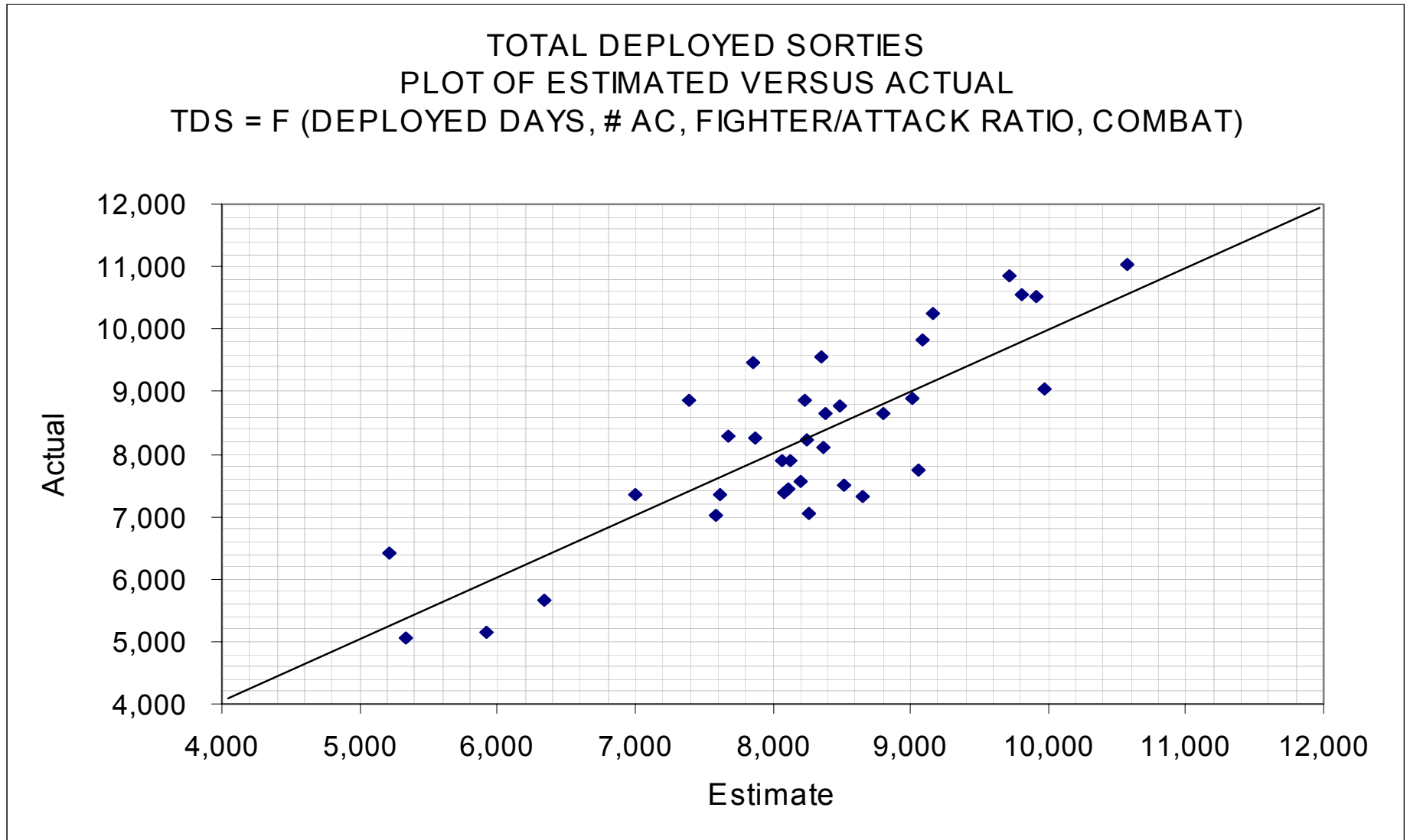
MC is a “dummy” type variable (enter 1 if the air wing engages in major combat, enter 0 for any other situation)

Statistics:

| Coefficient | T-Stat | Sig |
|-------------|--------|------|
| Intercept | 411.1 | 100% |
| DD | 5.7 | 100% |
| AC | 2.1 | 95% |
| FR | 2.2 | 96% |
| MC | 2.8 | 99% |

| | |
|-----------|-------|
| R-Squared | 70.6% |
| F-Stat | 18.1 |
| DOF | 30 |

Analysis Results - Hypothesis 2B



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Carrier Air Wing Model Application

- **Average values derived from the air wing dataset consisting of 35 deployments are substituted into the equation**
 - Average cost per aircraft is derived by first applying direct cost per flight hour by TMS (calculated using VAMOSOC data) to deployed hours by TMS for each deployment.
- **Input the expected values of deployment characteristics into the HPS and TDS equations**
 - Deployment Characteristics Required:
 - » Deployment Duration
 - » Total number of Aircraft
 - » Ratio of Fighter/Attack Aircraft to Support Aircraft
 - » Geographical Location and Type of Operation to be engaged
- **The output of the HPS and TDS equations are then inputs to the cost equation**

Carrier Air Wing Model Application

CVW Direct Operations \$ (FY03\$) =

$$\left(1,935,695 \right) \times \left(\frac{\text{HPS}}{2.13} \right)^{0.53} \times \left(\frac{\text{SPA}}{116} \right)^{0.19} \times \left(\frac{\text{AC}}{70} \right)^{1.18} \times \left(\text{AC} \right)$$

Flight Hours per Sortie (HPS) =

$$\left(2.13 \right) \left(\frac{\text{FR}}{2.00} \right)^{-0.14} \left(e^{(0.08 * \text{PW})} \right) \left(e^{(0.16 * \text{RW})} \right) \left(e^{(-0.10 * \text{IOTW})} \right) \left(e^{(0.16 * \text{AW})} \right) \left(e^{(-0.06 * \text{BOTW})} \right) \left(e^{(0.12 * \text{SOM})} \right)$$

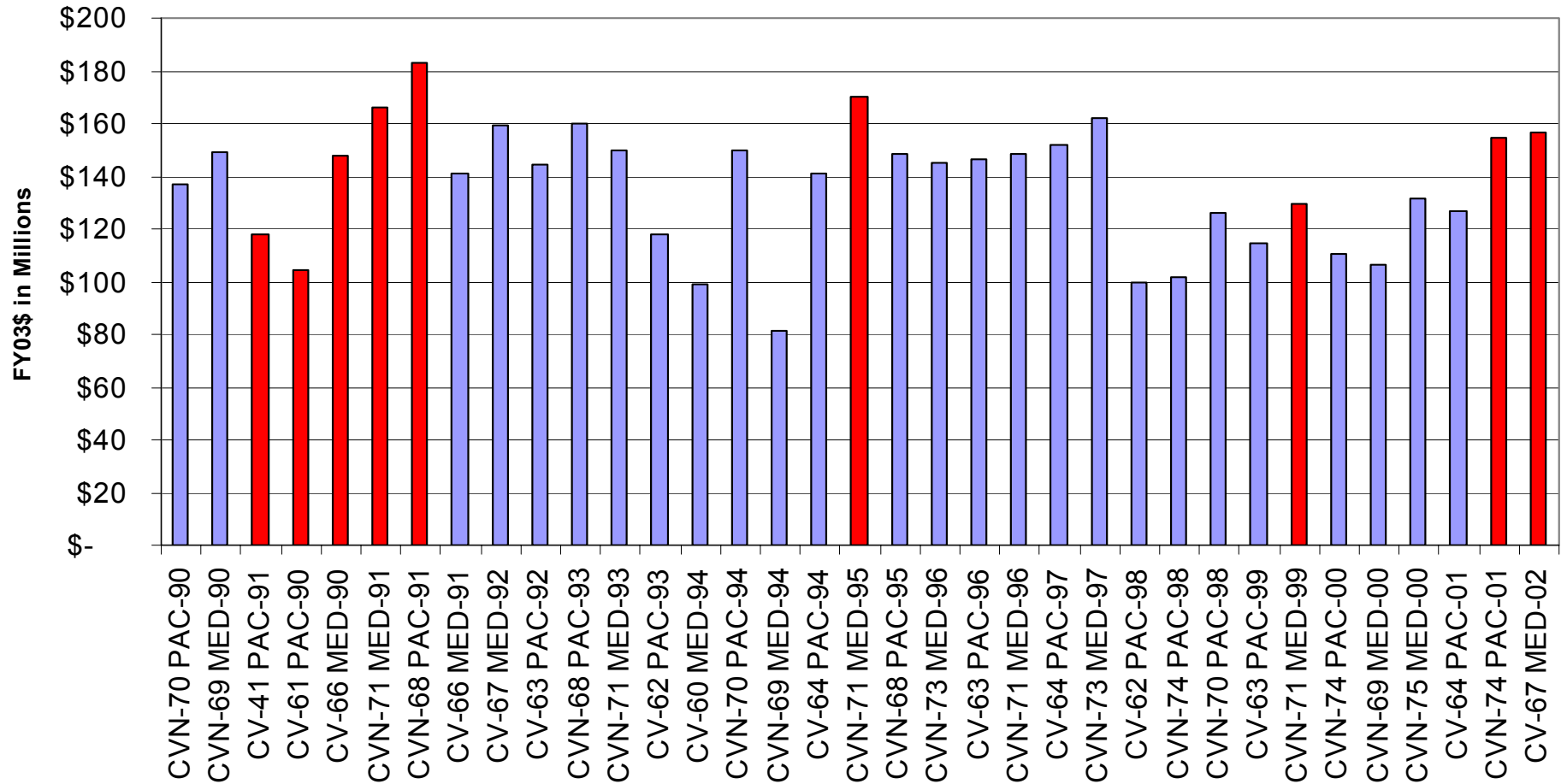
Total CVW Deployed Sorties =

$$\left(7,942 \right) \times \left(\frac{\text{DD}}{177} \right)^{0.92} \times \left(\frac{\text{AC}}{70} \right)^{0.53} \times \left(\frac{\text{FR}}{2.00} \right)^{0.29} \times \left(e^{(0.12 * \text{MC})} \right)$$

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Applying the model to history

Estimate of Historical Carrier Air Wing Costs (FY03\$)



Red Bars = Major Combat (MC)

Blue Bars = Operations other than War (OOTW)

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Carrier Battle Group Ship Analysis

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Hypotheses

1. The cost of battle group ship operations is dependent on the OPTEMPO of the battle group
 - Ship OPTEMPO can be measured in terms of the number of steaming hours and barrels of fuel expended on a deployment

2. Steaming hours and barrels of fuel are dependent on the type of operation engaged and the geographical location of the operation
 - A. Geographical location of the operation has a strong influence on steaming hours underway
 - B. Operation type has a strong influence on the rate of barrels of fuel expended (i.e., barrels per steaming hour underway, or BBLS/SHU)

Approach

- Develop two databases
 - Cost Database
 - Deployment Database
- Analyze the cost database to prove hypothesis 1
- Analyze the deployment database to prove hypotheses 2A and 2B

Analysis ground rules

- A sample size of 12 battle group deployments was selected from the population of 70
- Criteria for selecting deployments:
 - FY95 and later
 - CVN-68 (Nimitz) class carriers only
 - Deployment needs to start and end within the fiscal year (i.e., deployments that overlap fiscal years were not selected for analysis)
- Cost data was gathered from Navy VAMOSC
 - Normal battle group deployments are six months in duration. The lowest level of granularity within VAMOSC is 12 months (corresponding to the fiscal year). Therefore, each data point includes six months of non-deployment costs.
- Programmatic and technical data on deployments was gathered from VAMOSC and a variety of USN and other public sources (e.g., Naval Vessel Register, CHINFO, FAS, etc.)

Analysis Results – Hypothesis 1

Battle Group Cost of Operations (FY03\$) =

$$\left(n \right) \left(41,935 \right) \left(\text{CPS} \right) + \left(n \right)^{0.91} \left(5.0 \right) \left(36.5 \right) \left(\frac{\text{SHU}}{\text{SHIP}} \right) \left(\frac{\text{BBLS}}{\text{SHU}} \right)$$

Avg % Res. Err. =
3.66%

Variable Definitions:

COST = Battle group Operations \$ for a full fiscal year, during which a 6 month deployment occurs

n = Total number of ships in the battle group

CPS = Average crew per ship for ships in the battle group

SHU/Ship = Average steaming hours underway per ship (non-nuclear)

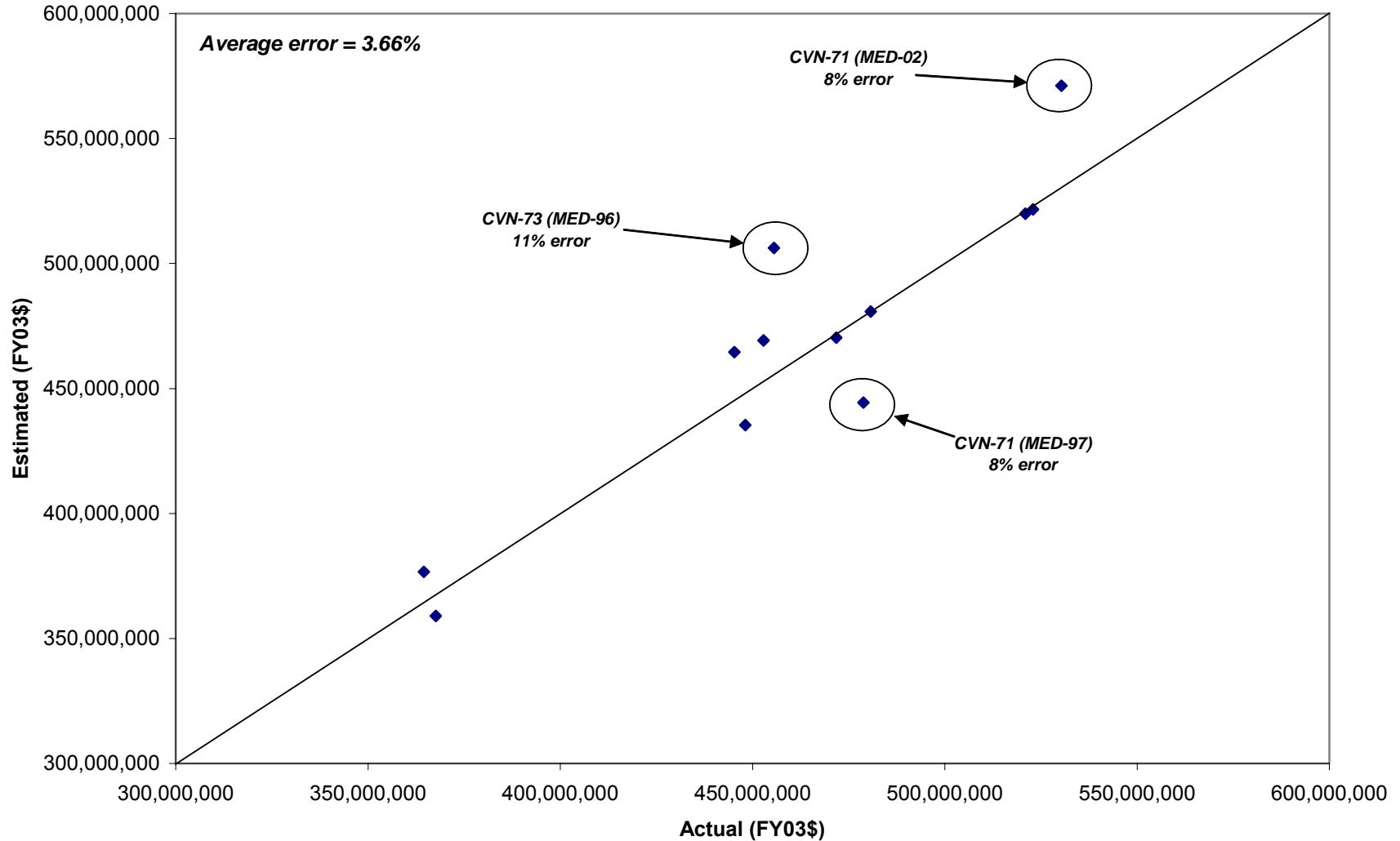
BBLS/SHU = Average barrels of fuel per steaming hour underway (non-nuclear)

Applicable data ranges:

| | | | | |
|-------|---|----------|---|-------|
| 10 | ≤ | n | ≤ | 16 |
| 450 | ≤ | CPS | ≤ | 635 |
| 2,822 | ≤ | SHU/SHIP | ≤ | 4,228 |
| 19.8 | ≤ | BBLS/SHU | ≤ | 31.1 |

Analysis Results – Hypothesis 1

Total Battle Group O&S Cost (less depot and modernization)



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Analysis Results – Hypothesis 2A

Steaming Hours Underway (SHU) =

$$\left(1,660 \right) \left(PV \right)^{0.04} \left(OPS \right)^{0.69} \left(e^{(0.13 * PG)} \right) \left(e^{(0.40 * AG)} \right) \left(e^{(0.70 * PG-SW)} \right)$$

Avg % Res. Err. =
0.91%

Variable Definitions:

- SHU = Steaming Hours Underway (non-nuclear ships only)
- PV = Number of Port Visits
- OPS = Number of operations engaged

Primary Location Variables (value = 1 if the condition applies):

- PG = Persian Gulf
- AG = Afghanistan
- PG-SW = Persian Gulf – Operation Southern Watch

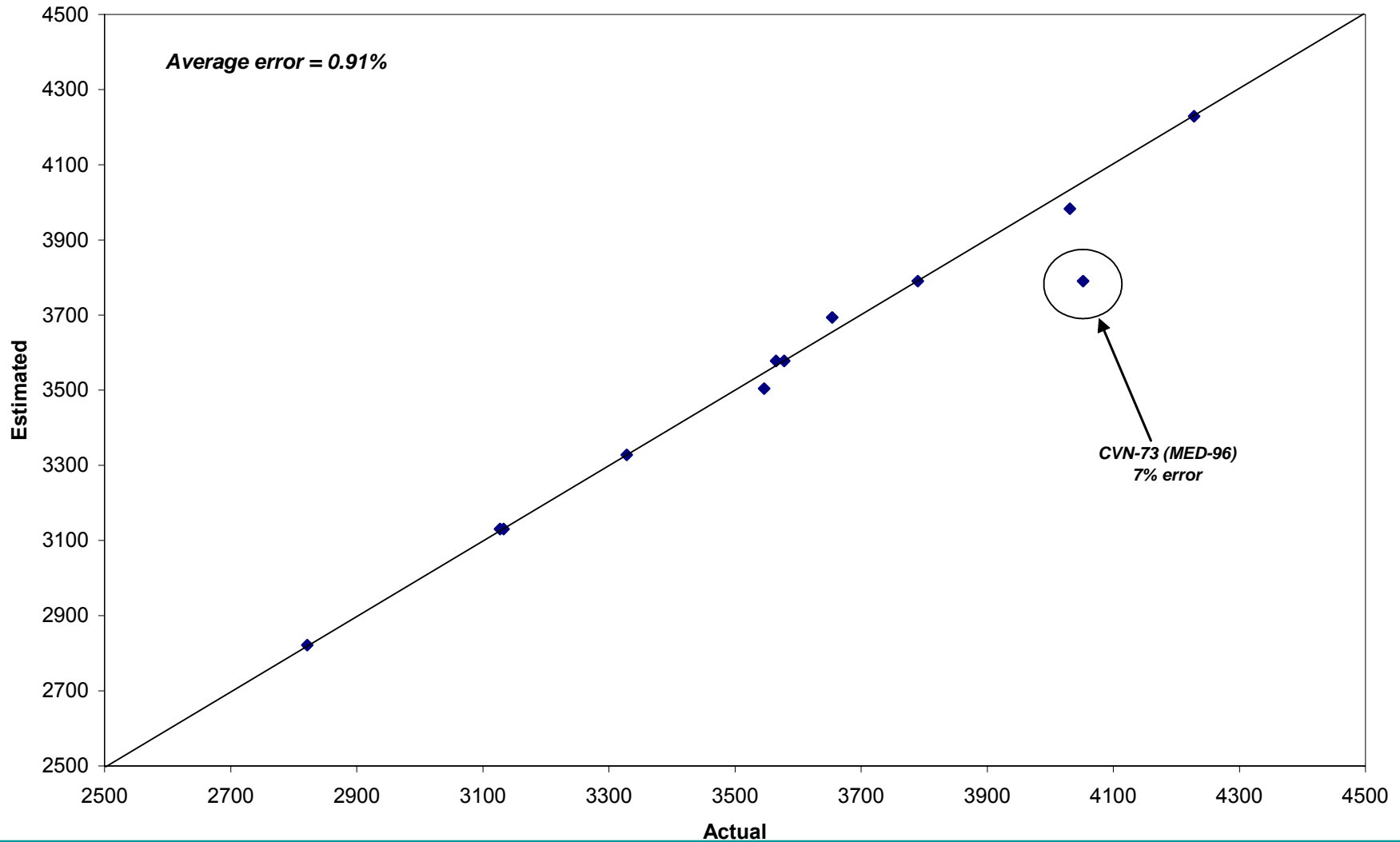
Note: The status quo (i.e., all location variables = 0) corresponds to an Adriatic Sea location

Applicable data ranges: 1 ≤ PV ≤ 7

 1 ≤ OPS ≤ 3

Analysis Results – Hypothesis 2A

Steaming Hours Underway



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Analysis Results – Hypothesis 2B

Barrels per Steaming Hour Underway (BBLs/SHU) =

$$\left(28.04 \right) \left(\frac{\text{LSD}}{14,336} \right)^{0.77} \left(e^{(-0.25 * \text{NFZ})} \right) \left(e^{(-0.07 * \text{PA})} \right) \left(e^{(-0.02 * \text{HUM})} \right) \left(e^{(0.01 * \text{WAR})} \right)$$

Avg % Res. Err. =
2.56%

Variable Definitions:

- BBLs/SHU = Barrels per Steaming Hour Underway (non-nuclear ships only)
- LSD = Average Light Ship Displacement across all battle group ships

Primary Operation Type Variables (value = 1 if the condition applies):

- NFZ = No Fly Zone
- PA = Peace Accords
- HUM = Humanitarian
- WAR = War or strike missions

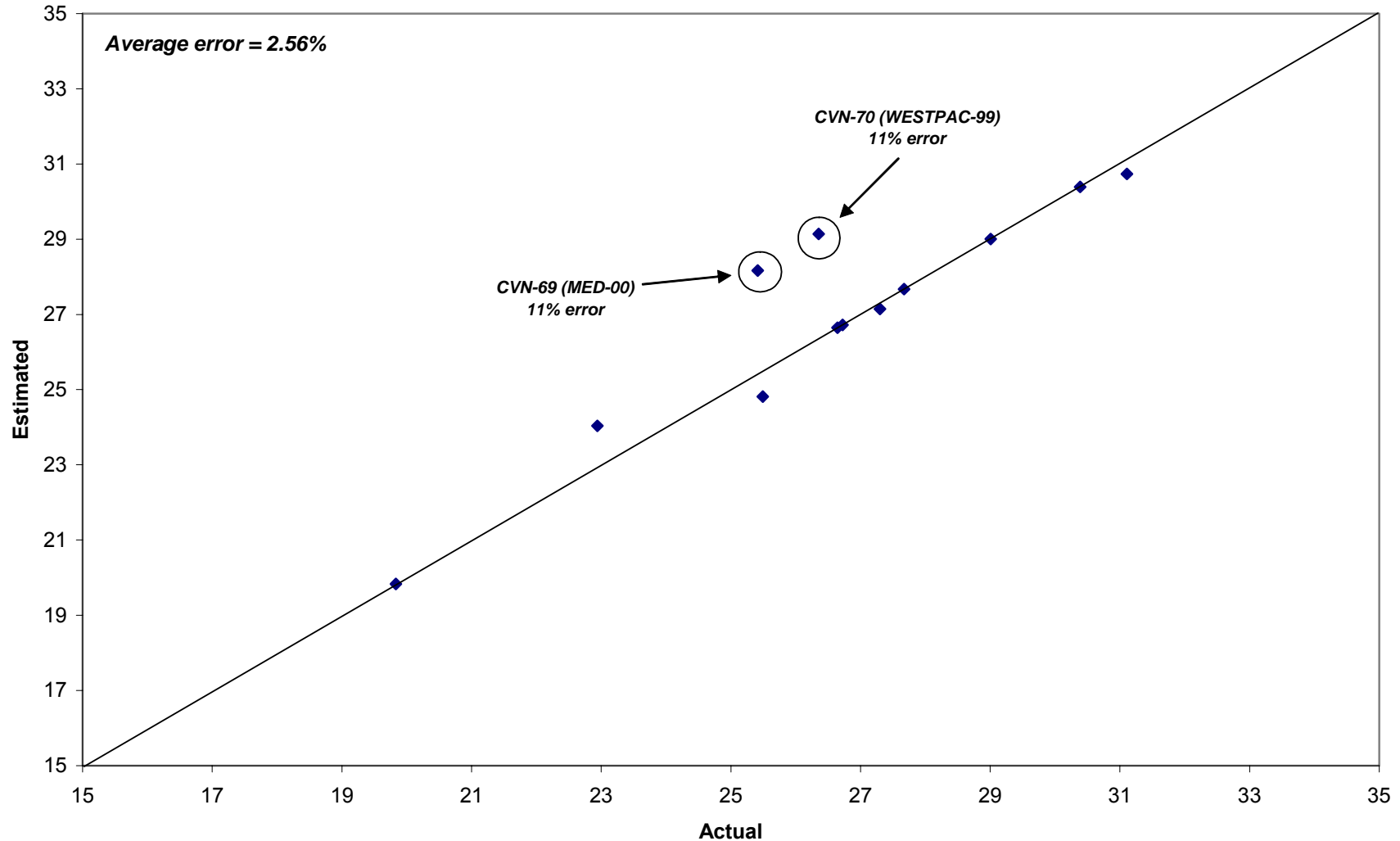
Note: The status quo (i.e., all operation variables = 0) corresponds to Operation Southern Watch

Applicable data ranges: 12,905 ≤ LSD ≤ 15,918

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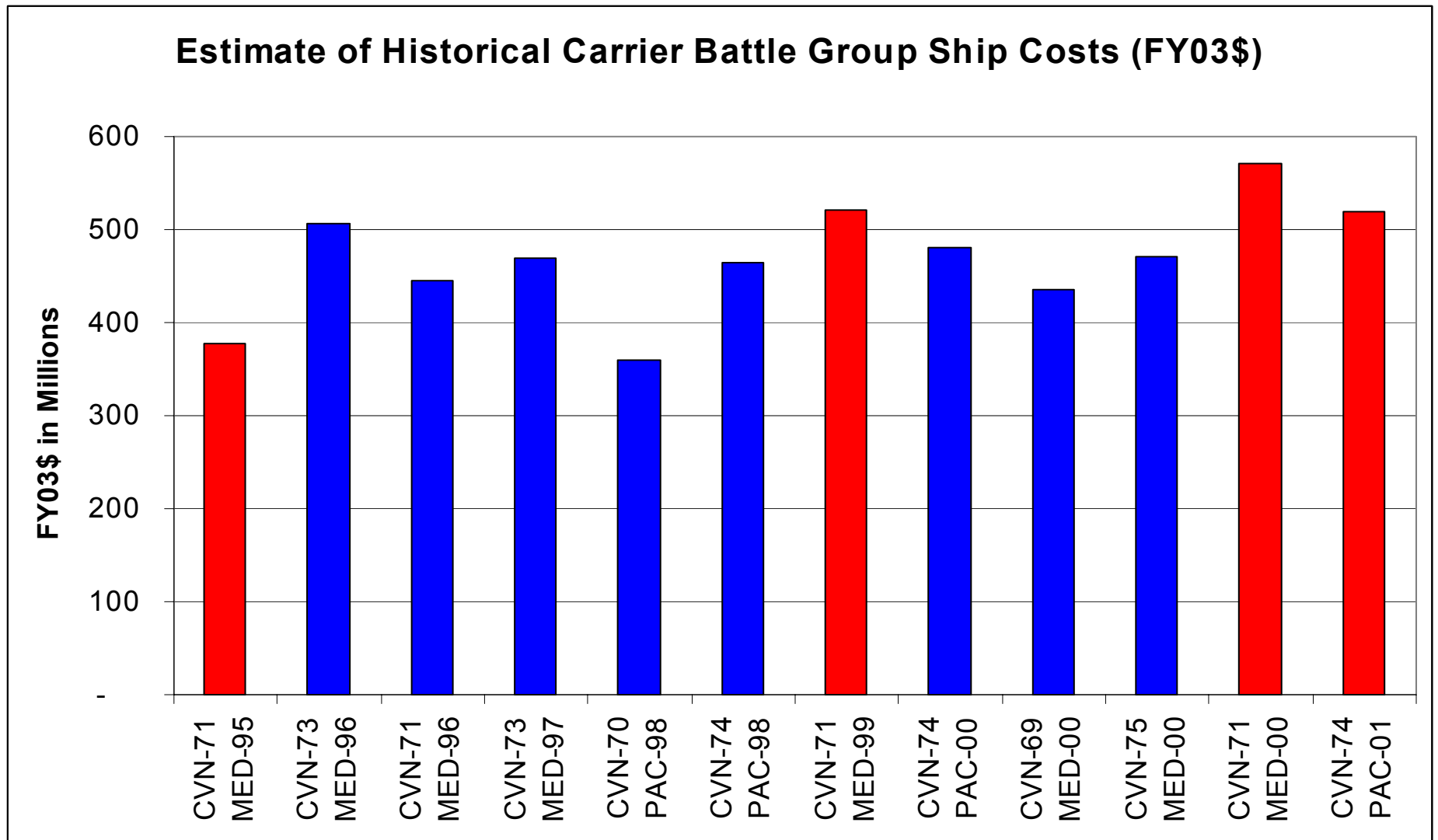
Analysis Results – Hypothesis 2B

Barrels per Steaming Hour Underway



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Applying the Model to History



Red Bars = Major Combat (MC)

Blue Bars = Operations other than War (OOTW)

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Conclusions

- Logical equations for OPTEMPO measures and cost were derived using a combination of VAMOSC data and carrier battle group characteristic data
 - Carrier Air Wing
 - » Number of aircraft sorties are a function of the deployment duration and purpose, and the size and composition of the air wing
 - » Sortie duration is a function of both the air wing composition and the operation type and location
 - » Air Wing Cost is a function of sortie rate and duration and air wing size
 - Battle Group Ships
 - » Steaming hours underway is a function of the battle group's destination (i.e., operating area)
 - » Barrels of fuel expended per steaming hour is a function of the battle group's size and primary mission
 - » Cost of the operation is a function of steaming hours, barrels of fuel expended, and crew size

Model Limitations

- **Model Inclusions:**
 - Individual deployments
 - USN and USMC
 - Carrier Strike Group Surface Ships
 - Carrier Air Wings
 - USMC squadrons that deploy as part of the Carrier Air Wing
- **Model Exclusions:**
 - Entire operations (e.g. Operation Desert Storm)
 - Other armed services (USAF, USA)
 - Submarines
 - LAMPS Helicopter Squadrons
 - Helicopter Support Squadrons
 - Amphibious Strike Group Deployments
 - » Amphibious Ships
 - » Amphibious Assault Aircraft
 - Operational ordnance costs

Total Fleet Level Analysis

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Prepared for:

Department of Defense Cost Analysis Symposium

13 February 2004

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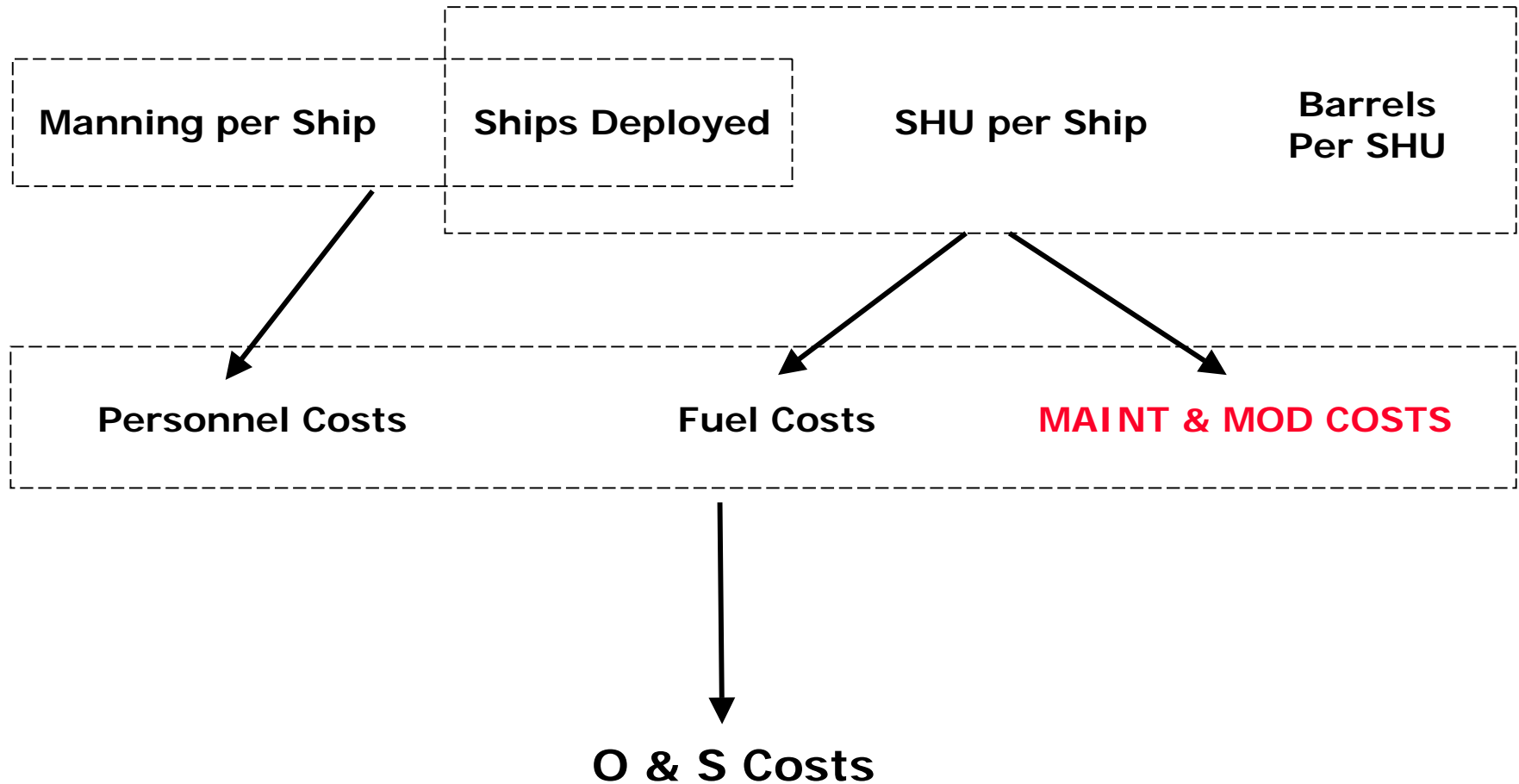
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Purpose of Research

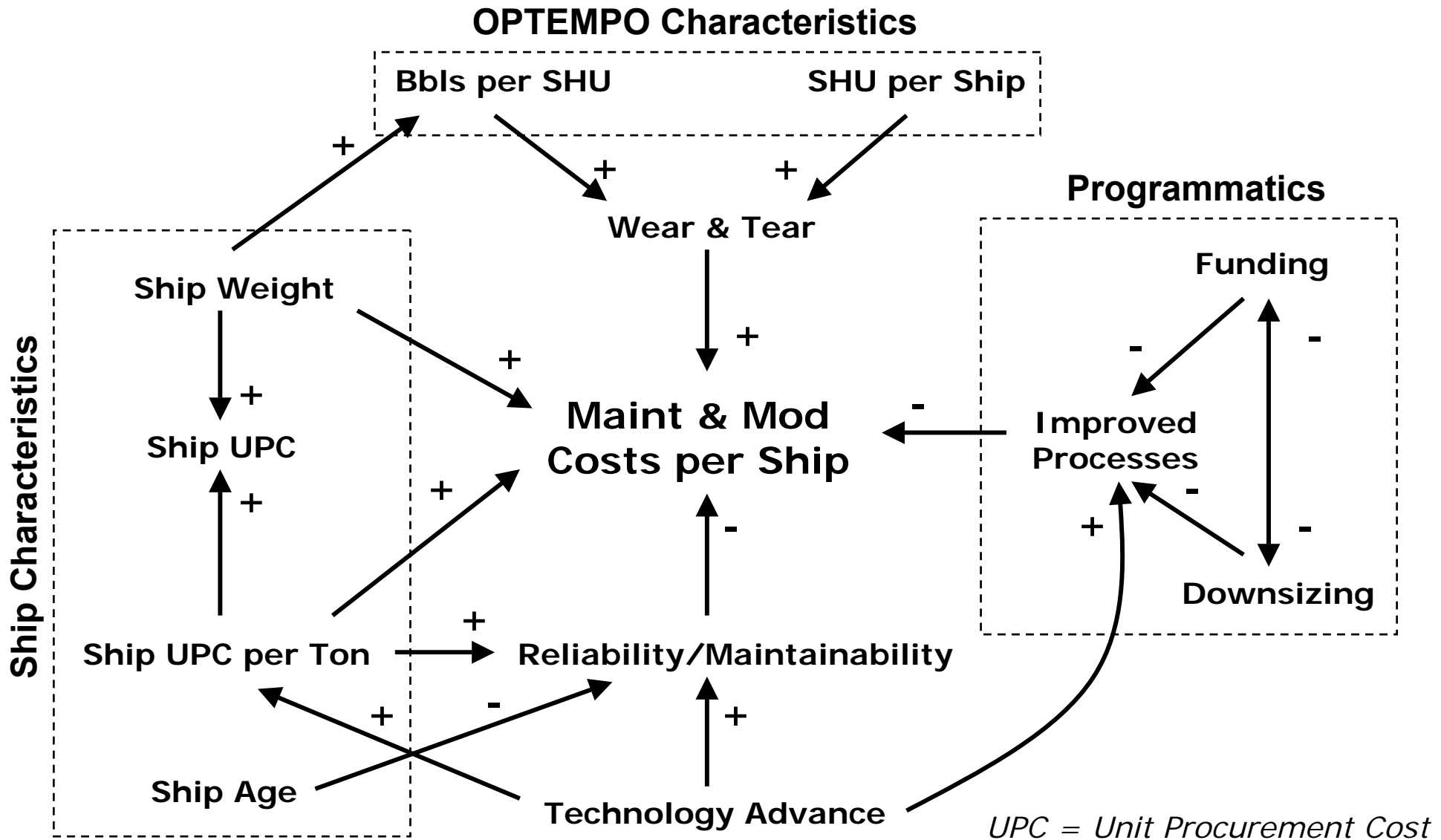
- Use historical VAMOSC data to develop fleet level cost estimating relationships sensitive to changes in OPTEMPO
 - Personnel
 - Fuel
 - Maintenance & Modernization
- Utility
 - Provide insight into impact of ship operating and support cost drivers
 - Provide improved data validation techniques for VAMOSC

Overview



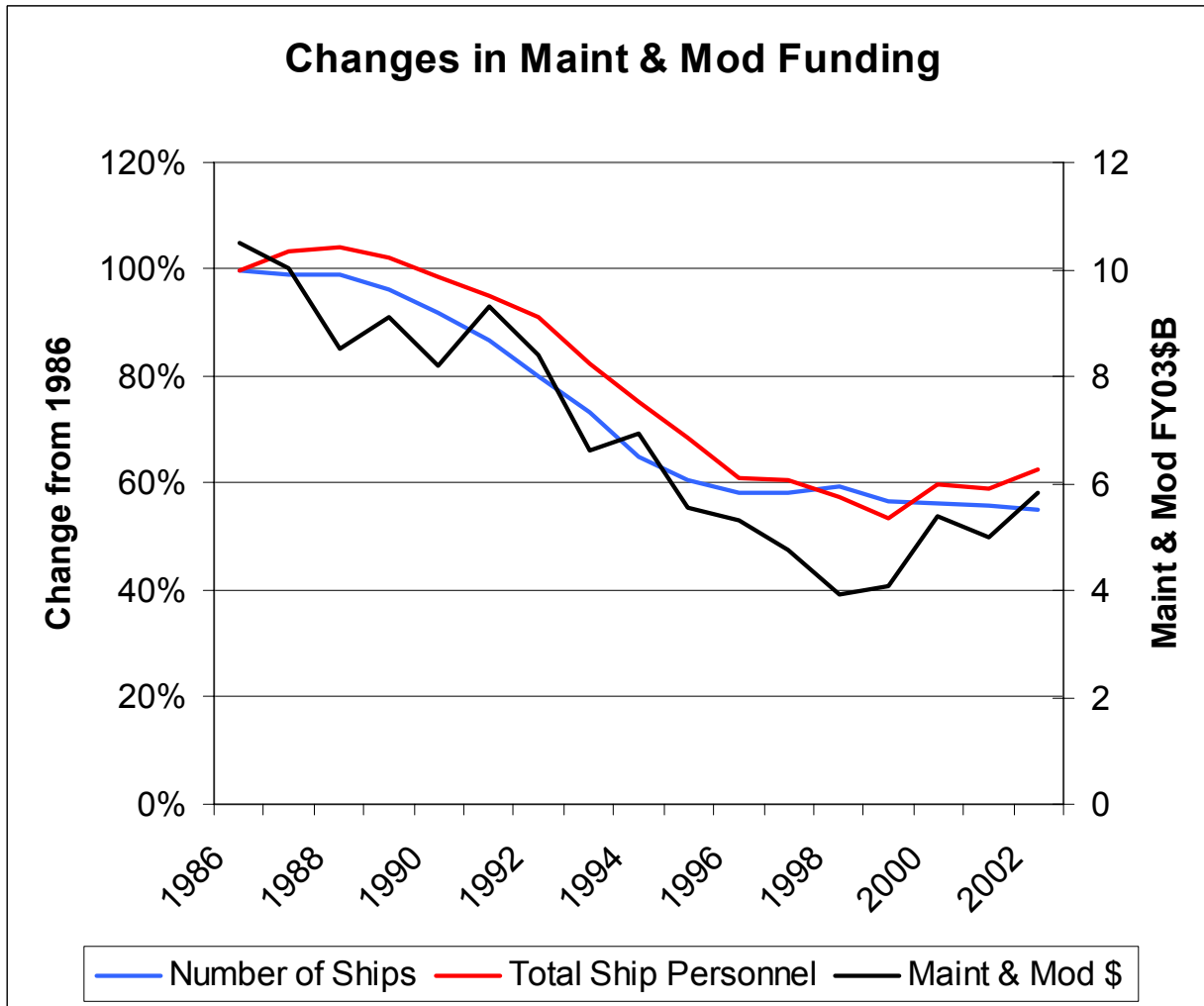
SHU = Steaming Hours Underway

Hypothesis



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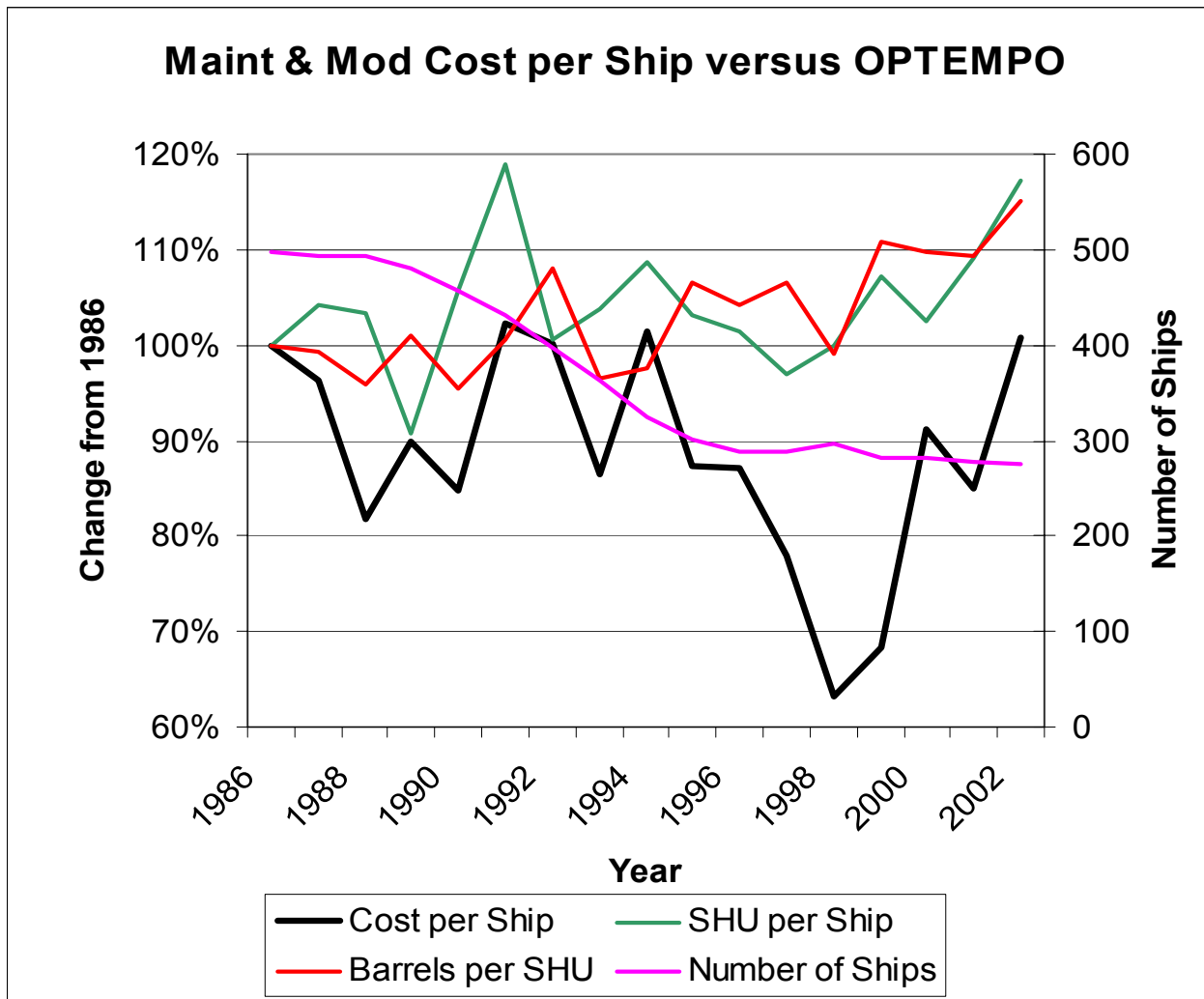
Maint & Mod \$ vs. Number of Ships



Since 1986,

- Number of ships, total ship personnel, and total maint & mod funding have all decreased by about 40%

Maint & Mod \$ vs. OPTEMPO

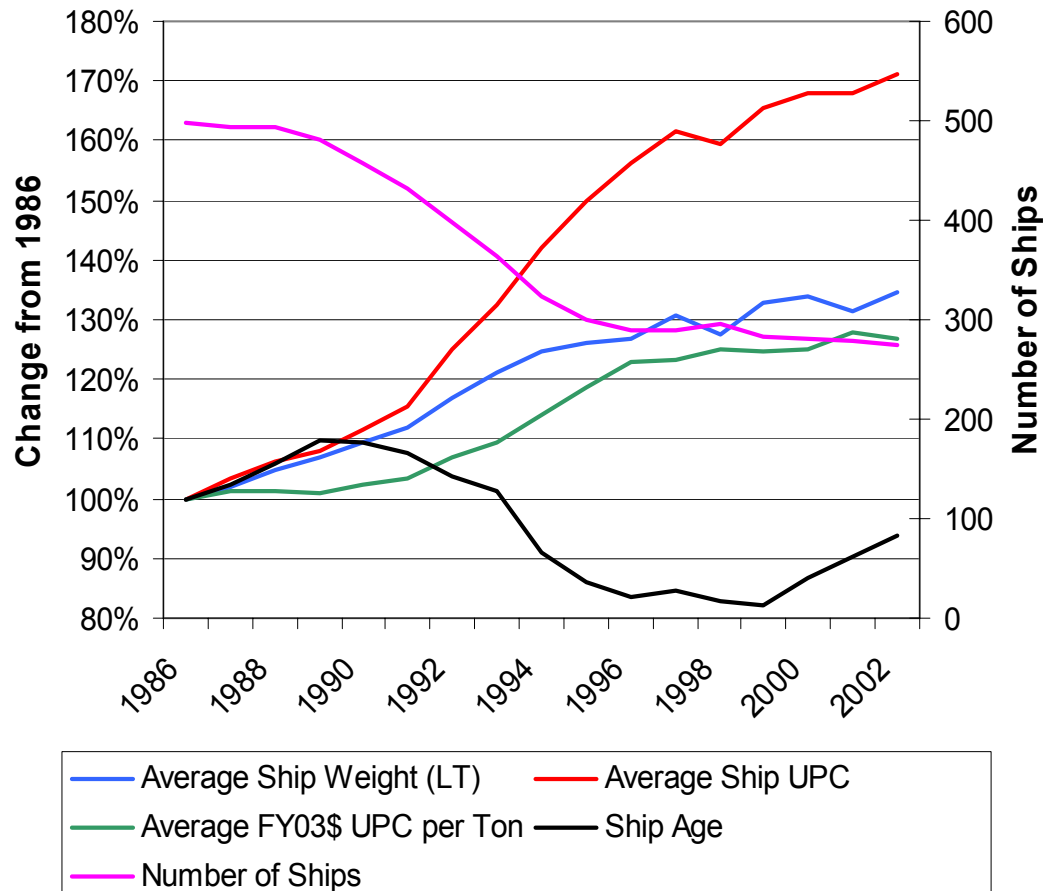


Since 1986:

- Number of ships (right scale), has decreased by 40%
- Steaming hours underway (SHU) per Ship and Barrels per SHU have both increased by 15-20%
- Yet maint & mod \$ per ship in FY02 are about the same as in 1986, and in some years have been significantly lower

Changes in Ship Characteristics

Changes in Ship Characteristics



Since 1986:

- Number of ships (right scale), has decreased by 40%
- Average ship age has varied significantly, but is now just slightly below 1986
- Average ship weight and average ship unit procurement cost per ton have both increased by 25-35%, causing the average ship unit procurement cost to increase by 70%
- Yet, from the previous slide, we know that the maint & mod costs per ship are about the same

Maint & Mod Cost Relationship

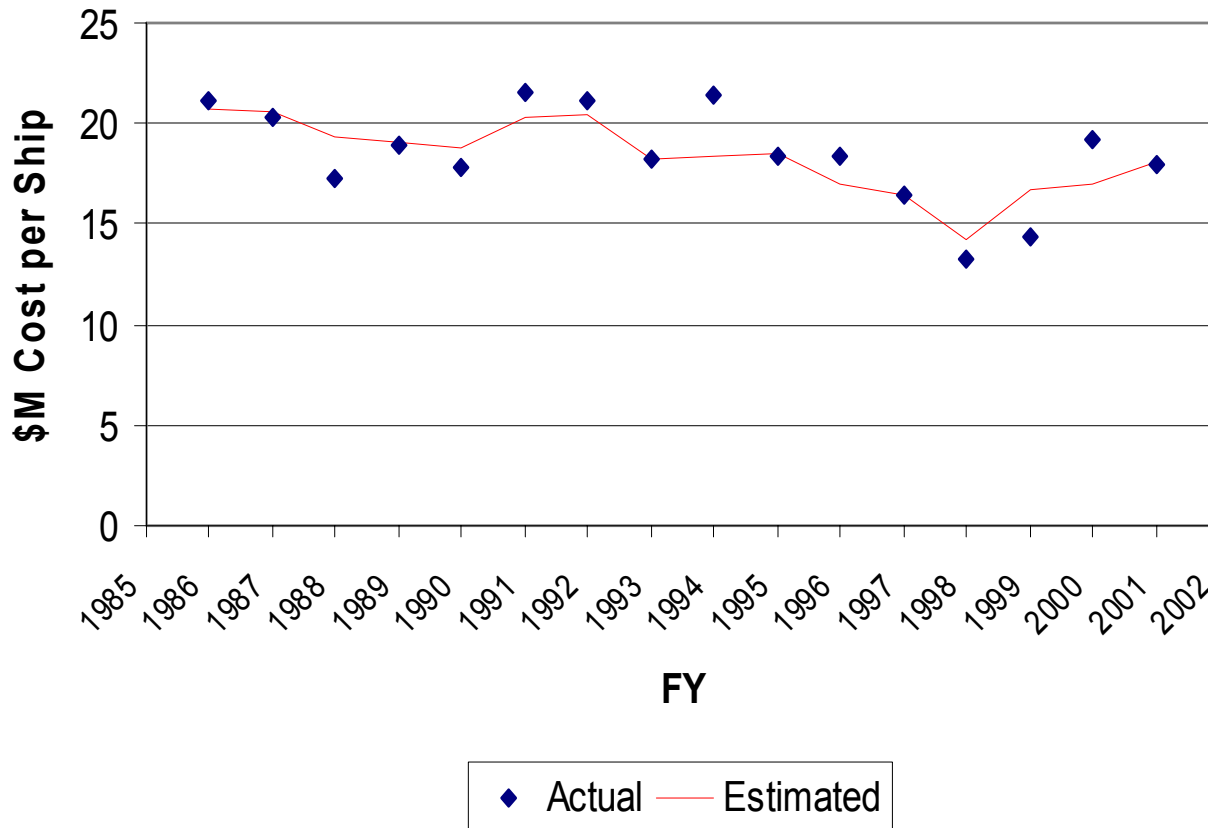
Maint. & Mod. FY03\$ per Ship =

$$\left(21,819,910 \right) \left(\frac{\text{AVG WT (LT)}}{7,522} \right)^{1.0} \left(\frac{\text{SHU / Ship}}{1,700} \right)^{0.41} \left(\frac{\text{BBLs / SHU}}{22.8} \right)^{1.0} \left(\frac{\text{Ship Age}}{16.9} \right)^{0.13} \left(\frac{\text{Ships-1}}{\text{Ships}} \right)^{0.4} e^{(-0.048(\text{year}-1986))} e^{(0.05(\text{year}-1999))}$$

- As ship weight (LT) increases, maint & mod \$ increase
- Increases in SHU per ship and Bbls per SHU result in increases in maint & mod \$ per ship
- As ships age, they require more maintenance & modernization
- As number of ships decreases, overhead must be distributed among fewer ships (model constrained to a one-year impact)
- Data shows a 5% annual decrease in funding from 1987-1999 and a 5% annual increase from 2000-2002

Estimated vs. Actuals

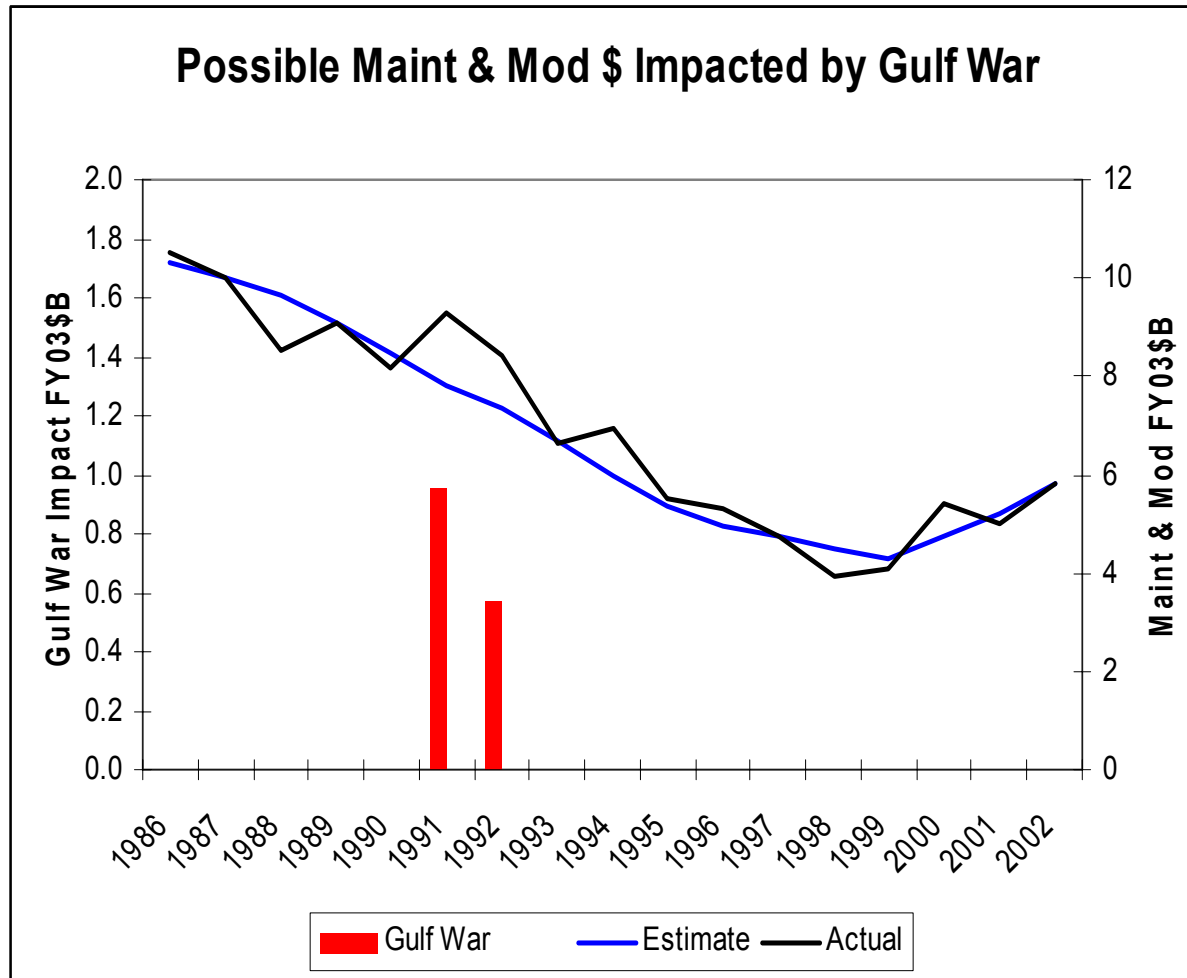
Maint & Mod \$M per Ship
Estimated versus Actuals



- This is a plot of what our equation predicts by year vice actual maint & mod funding

- The standard error is about 5.5%

Gulf War Impact Analysis



This is a slightly different plot. It reflects all of our preceding variables except OPTEMPO.

Note that FY91 and FY92 are underestimated by about \$1.6B. This could be the impact of the Gulf War. If so, we could see a similar impact from the current conflict.

Conclusions

- Today we spend about the same for Maint & Mod per ship as compared to 1986.
- When normalized for weight, UPC, and OPTEMPO this translates to ~ 50%.
 - Possible explanations include:
 - » Process improvements gained through downsizing (workload efficiencies, maintenance philosophy, etc.)
 - » Improved Reliability/Maintainability