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DEFINING THE FUTURE

How Age Affects Operations and Support Costs Differently Across Platforms

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Outline

- **Background**
- **Element Definitions**
- **The Age Effect in Ships**
- **The Age Effect in Rotary Wing Aircraft**
- **Conclusions**

Background

- **Issue:**

- Age is believed to have an impact on Operations and Support costs but it is not known if age affects all platforms or, for the platforms it does affect, if it affects all platforms in the same manner.

- **Why is this important?**

- For budgeting purposes it is often important to see how much funding will be needed in a given year. Without an age effect, it is assumed that the same amount of money will be required for every year of life, when this is in fact not the case.

- **Problem**

- In general, an age effect has been elusive. To date, Northrop Grumman has shown an age effect in O&S cost for ships, but no other program types had been explored. It cannot be assumed that age affects all platforms in the same way it does ships.

- **Solution:**

- Show how age affects platforms other than ships and discuss the broader implications for as yet unexplored platforms.

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Where Age Effects Are Seen

It has previously been observed that an age effect can be seen in total O&S costs for ships. At a lower level, age effects were determined to exist in the following elements:

- Scheduled Overhaul (first order)
- Repair Parts (first order)
- Centrally Provided Material (second order)
- Equipment Rework (second order)
- Naval Aviation Depot Maintenance (second order)
- Fleet Modernization (third order)
- Other Depot Maintenance (third order)

Some of these age effects were first presented at SCEA in June 2003: *Ship Scheduled Overhaul Costs Over Time*, Summerville, Coleman, Dameron, Leach and then updates and newly discovered age effects were discussed at SCEA in June 2004: *Operating and Support Costs Over Time*, Grinnell, Summerville, Dameron, Coleman.

Where Age Effects Are Seen cont'd

New research shows an age effect in aircraft, both rotary and fixed wing. To date, age effects have been shown in the following elements:

- Consumables
- Aviation Depot Level Repairables
- Roll-up of Total O&S costs

Ship Element Definitions

- **Scheduled Overhaul:**

Includes the labor, material, and ship repair facility overhead costs of scheduled depot maintenance for ships in the operating forces.

- **Repair Parts:**

Includes the cost for spares, both on-board and off-board the ship, used to repair items on the ship. Also includes the cost of exchanges – replacing a part with a new part and sending the old one back to get it fixed.

- **Centrally Provided Materials (CPM):**

Includes the cost of materials to modernize equipment on the ship.

- **Equipment Rework:**

Includes the cost of overhaul, rework, or repair of major ordnance equipment; hull, mechanical, and electrical (HM&E) equipment; and electronic equipment.

Ship Element Definitions cont'd

- **Naval Aviation Depot (NAD) Maintenance:**

Includes the cost of depot maintenance performed by the Naval Aviation Depot (NADEP). For surface combatants, the primary cost in this element is the cost associated with rework of the gas turbine engines.

- **Fleet Modernization:**

Includes the cost of labor, material, and ship repair facility overhead associated with improving a ship's safety, maintainability, or technical characteristics. These improvements are made by altering or modifying a ship, or installing new equipment.

- **Other Depot Maintenance:**

Includes the cost of planning overhauls and alterations, and procurement of equipment for overhauls and alterations by the Planning and Engineering or Repair and Alterations (PERA).

Aviation Element Definitions

- **Aviation Depot Level Repairables:**

Includes the cost for the retail purchase of repairable components from both the Navy supply system and from commercial sources.

- **Consumables:**

Includes the cost of organizational maintenance materials, flight clothing, safety equipment, and administrative supplies for Navy and Fleet Readiness Squadron (FRS) aircraft. This report category does not include Contractor Logistics Support (CLS) costs.



A Recap of the Age Effect in Ships

Data

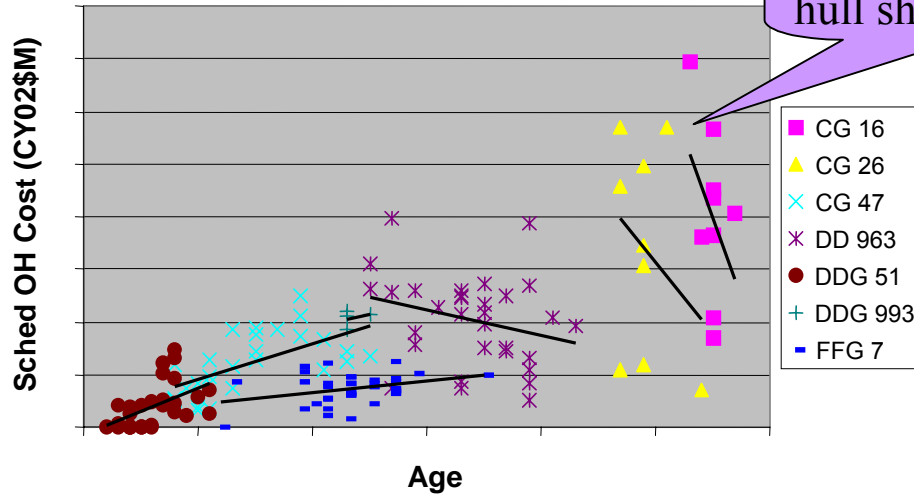
- **Costs were downloaded from the Navy's VAMOSC¹ database.**
- **Data for the following ship classes was included in the analysis:**
 - Cruisers – CG 16, CG 26, CG 47
 - Destroyers – DD 963, DDG 51, DDG 993
 - Frigates – FFG 7
- **Hull data was preferred in the analysis because it provides more data points, but sometimes there was too much variability in the data so class average data was used for some elements.**
- **Average age was calculated in years from the commissioning date.**

¹Visibility and Management of Operating and Support Costs, <http://www.navyvamosc.com>

Scheduled Overhaul

Option #1

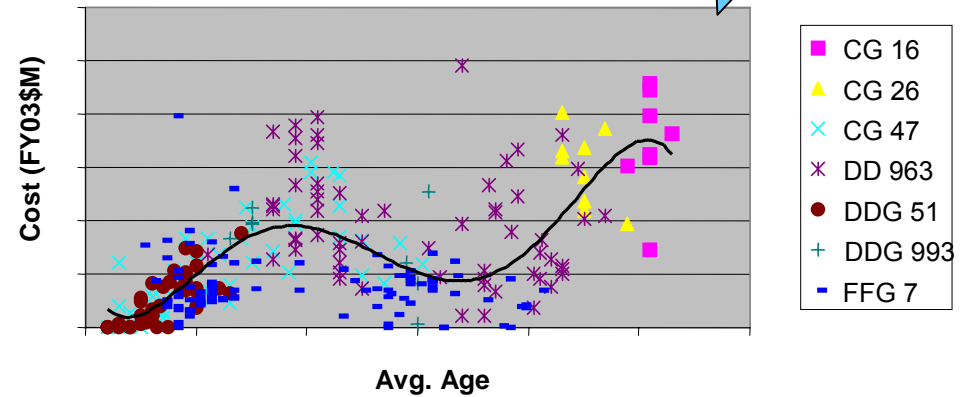
Cost vs. Age



Two average costs per hull show new pattern with an age⁵ regression line.

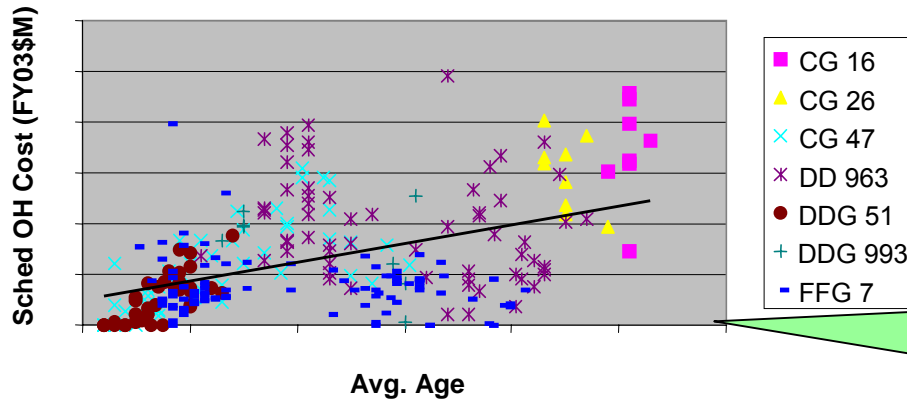
Option #2

Cost vs. Avg. Age



Option #3

Cost vs. Avg. Age



Best option because it takes into account the overhaul cycles without the estimate dropping off dramatically after age 28.

Repair Parts

<i>Regression Statistics</i>	
Multiple R	0.892
R Square	0.796
Adjusted R Square	0.790
Standard Error	259,036.681
Observations	149

Good R² value

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	4	3.768E+13	9.421E+12	140.405	1.177E-48
Residual	144	9.662E+12	6.710E+10		
Total	148	4.735E+13			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept		150,881.030	(3.045)	0.003	(757,626.150)	(161,170.795)
Avg Age		19,950.347	10.184	1.106E-18	163,747.820	242,614.534
Avg Age^2		694.478	(9.036)	9.846E-16	(7,647.783)	(4,902.409)
400		333.739	2.242	0.026	88.749	1,408.069
700		397.548	10.295	5.697E-19	3,307.094	4,878.663

400 and 700 are part of the Ship WBS. 400 is Command & Control and 700 is Armament. Here the weights of the SWBS are used in the regression analysis.

Age² is significant

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Age Effects in Other Cost Elements

2nd and 3rd order age effects were found in:

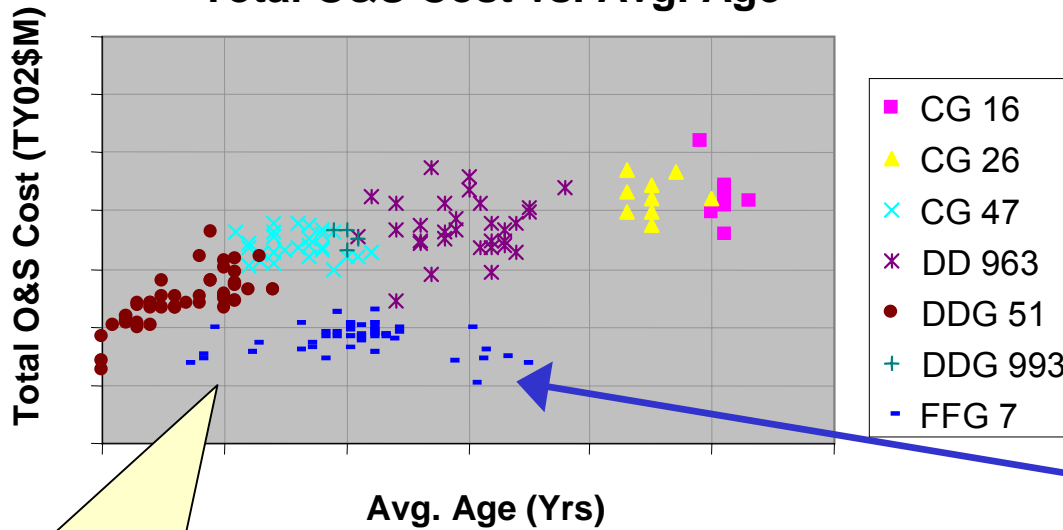
- **Centrally Provided Materials (CPM)**
 - Since CPM is the cost of materials required to modernize, this cost rises for older ships. CPM factors off of Scheduled Overhaul. This is logical because modernization mostly takes place when the ship is at the depot for repairs.
- **Fleet Modernization**
 - FM is the labor portion of modernization. It's cost is based on the cost of CPM – the more costly the material is to modernize, the more the labor will cost. In addition, the cost rises and falls as it does with Scheduled Overhaul.

Age Effects in Other Cost Elements cont'd

- **Equipment Rework**
 - Equip. Rework is the cost of overhaul, rework, or repair of major ordnance equipment; hull, mechanical, and electrical (HM&E) equipment; and electronic equipment. It's cost is based on Scheduled Overhaul costs.
- **Naval Aviation Depot Maintenance**
 - NAD Maint. includes costs associated with rework of gas turbine engines. The cost is based on Scheduled Overhaul costs.
- **Other Depot Maintenance**
 - Other Depot Maint. is the cost of miscellaneous depot maintenance, including planning for the overhaul. It's cost is related to the cost of NAD Maint.

Total O&S Cost

Total O&S Cost vs. Avg. Age

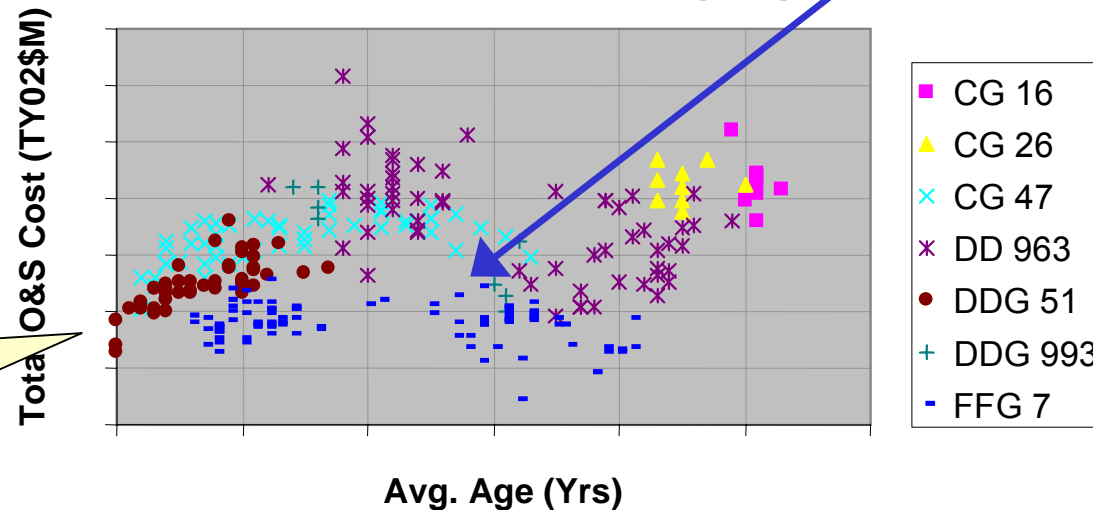


Notice that the Frigates are not in line with the other ships. This is due to the weight effect that also is present – the Frigates are much lighter than the other ships.

Using the average of all available O&S costs we see the age-squared pattern

Taking two averages as done for scheduled overhaul we see the age^5 pattern emerge at the Total O&S level.

Total O&S Cost vs. Avg. Age



Summary of Ship Age Effects

- **The O&S cost for ships increases for most of a ships life and then decreases towards the end when repairs may be needed, but they are just not made.**
 - This is what has been termed the “age-squared effect.”
 - This effect is akin to car maintenance: towards the end of a car’s life repairs may be needed, but as long as the car is running the owner chooses not to make them.
- **The age effect is prominent in ships cost because the cost for some elements is dependent on the cost of an element which is affected by age. So we see second and third order effects.**
- **Minus the Frigates, all the classes tend to fall in line so it is easy to spot age effects.**
 - It is important to note however that weight is a factor in ships cost and explains why the Frigates tend to show lower cost than other ships at the same age.



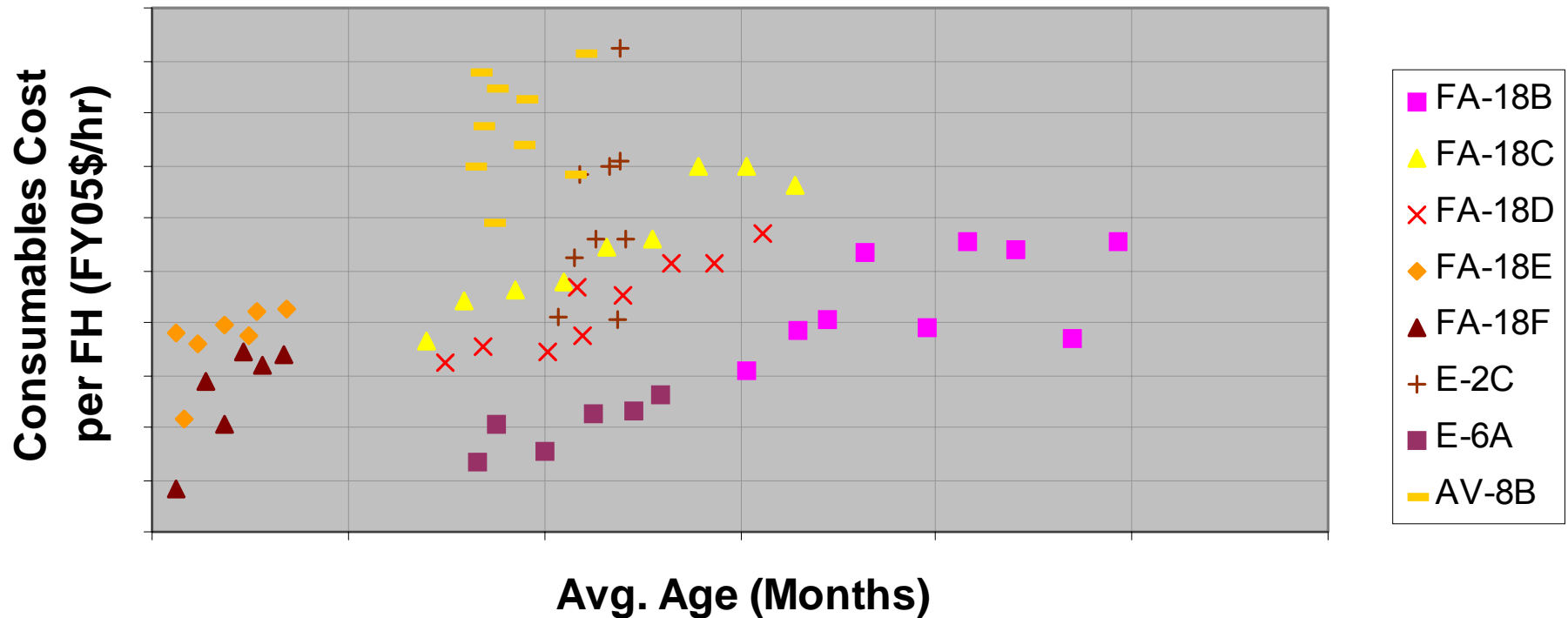
The Age Effect in Aircraft

Data

- **Data was downloaded from the VAMOSOC database. Data obtained from VAMOSOC includes cost, flight hours, and average age (calculated in months).**
- **The following type/model/series (T/M/S) were used in the analysis:**
 - **Fixed Wing**
 - **Strike Fighters – F/A-18B, C, D, & E, AV-8B**
 - **Other – E-2C (Airborne Early Warning), E-6A (Airborne Comms for Subs)**
 - **Rotary Wing – HH-60H, MH-60S, SH-60B, SH-60F**

Consumables – Fixed Wing

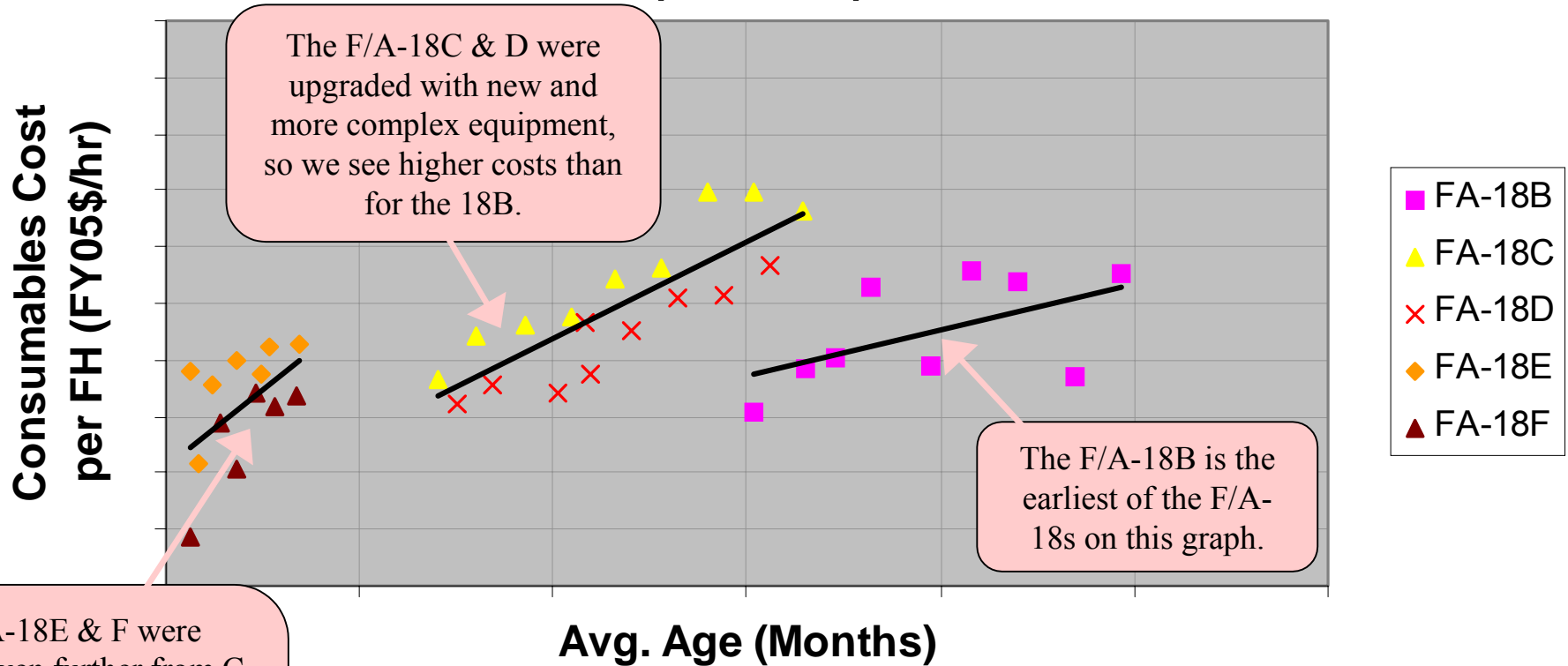
Consumables Cost per FH vs. Avg Age (Fixed Wing A/C)



Unlike ship classes, the cost for fixed wing type/models (T/Ms) do not fall nicely in line with each other. There is possibly another parameter affecting cost, similar to how weight affects ship cost.

Consumables – F/A-18s

Consumables Cost per FH vs. Avg Age (F/A-18s)

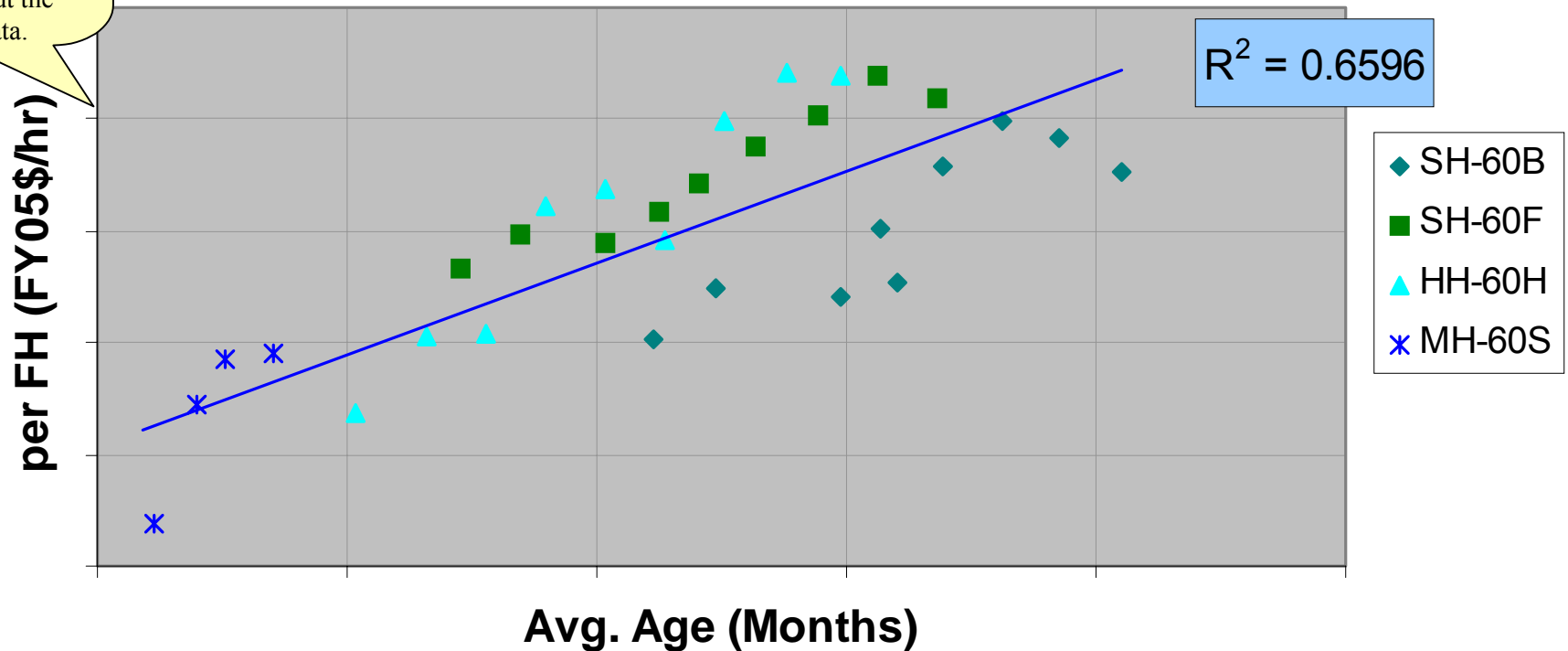


While the T/Ms do not line up, the series that make up the F/A-18 T/M do line up as expected.

Consumables – Rotary Wing (H-60s)

Notice that this scale is different from the Fixed Wing graphs so the graphs should not be compared other than general observations about the trends in the data.

Consumables Cost per FH vs. Avg Age (Rotary Wing A/C)



In rotary wing aircraft we see a consistent pattern across the H-60s. The SH-60B appears to fall a little below the other H-60s, so again, there may be another parameter at play here.

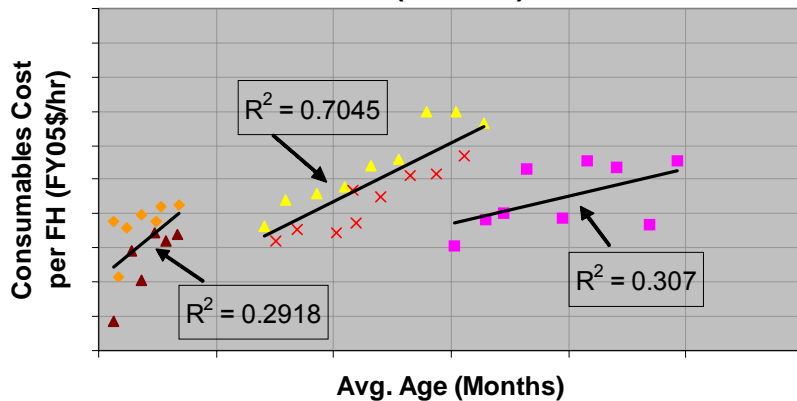
Do Costs Decrease for Older Aircraft?

Fixed Wing (F/A-18):

It's difficult to discern whether or not costs drop off towards the end of an aircraft's life due to few data points for older aircraft. Based on the rapid cost growth in the early years of the F/A-18E & F one would hope that the cost growth slows some. Perhaps a power curve would be in order?

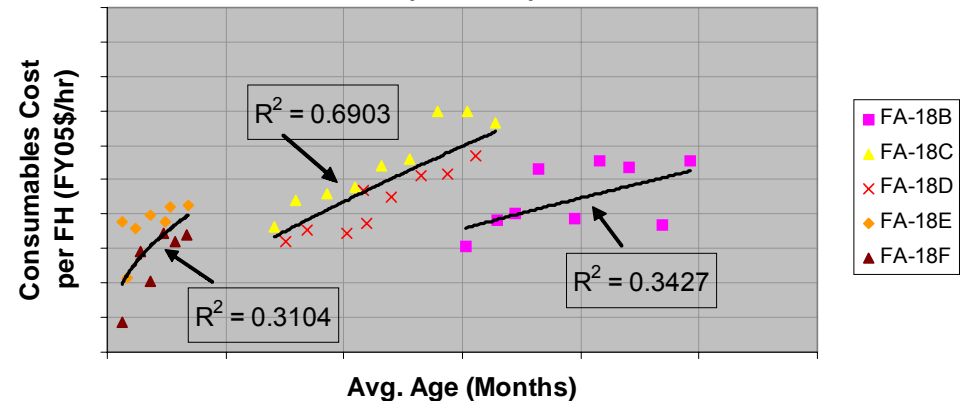
LINEAR

Consumables Cost per FH vs. Avg Age (F/A-18s)



POWER

Consumables Cost per FH vs. Avg Age (F/A-18s)



The power curves show little or no improvement in R². This is not enough evidence to warrant moving away from a linear CER.

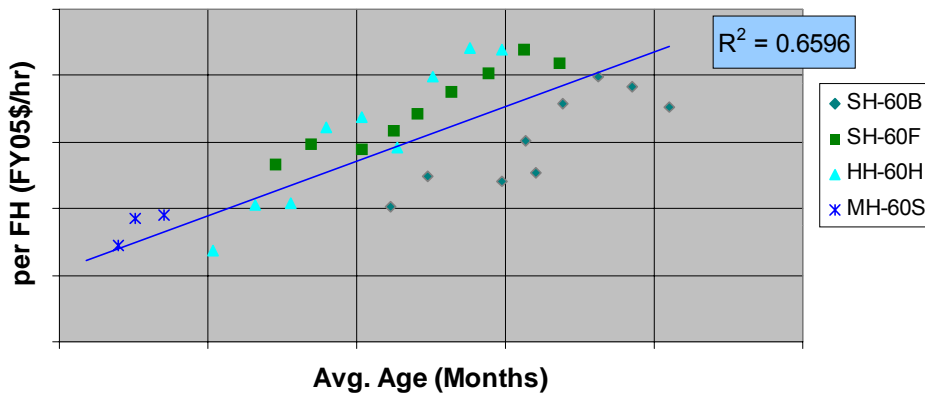
Do Costs Decrease for Older Aircraft?

Rotary Wing:

Again, it's somewhat difficult to tell whether or not there is a curve in the data due to few data points at the beginning and end of an aircraft's life.

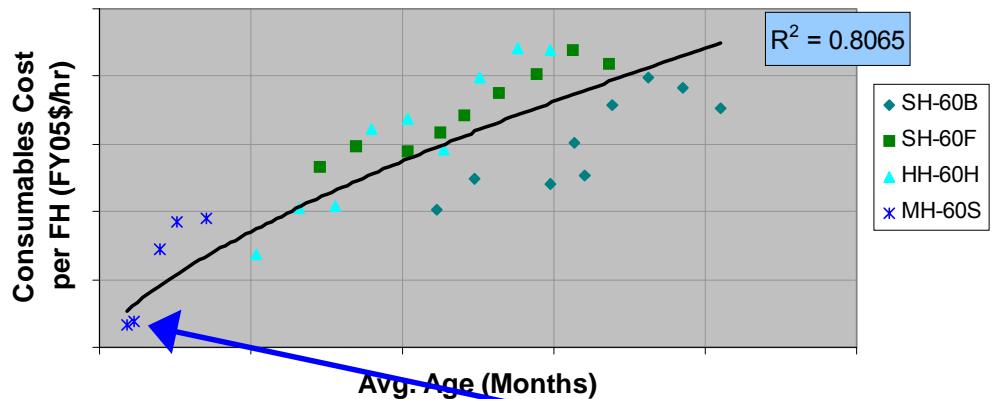
LINEAR

Consumables Cost per FH vs. Avg Age
(Rotary Wing A/C)



POWER

Consumables Cost per FH vs. Avg Age
(Rotary Wing A/C)



The power curve is mostly affected by the **2 earliest MH-60R data points**. The power curve was plotted again without those 2 points and the R^2 value decreased from the R^2 value for the linear CER. Again, it seems linear is the best fit.

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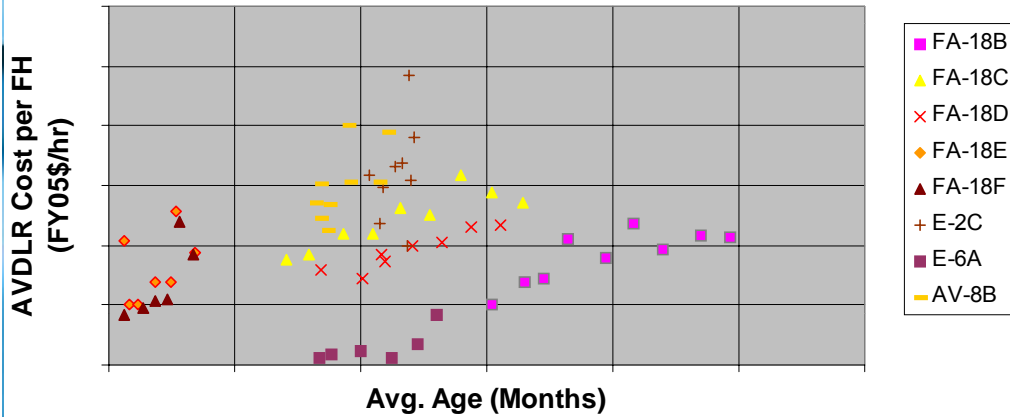
Does a Linear CER Make Sense?

- **Yes, a linear relationship between cost and age makes sense for aircraft.**
- **Why?**
 - We do not want to take a chance on aircraft falling out of the sky, so most breakages are treated as critical and are fixed. Even if the aircraft will be out of service in a couple of years, for the last few years it remains in service it needs to remain capable of flying and meeting safety requirements.
- **This is different from ships because there are a lot of parts to a ship and not all of them are critical. It is possible that several things may need repair but the ship is still seaworthy.**

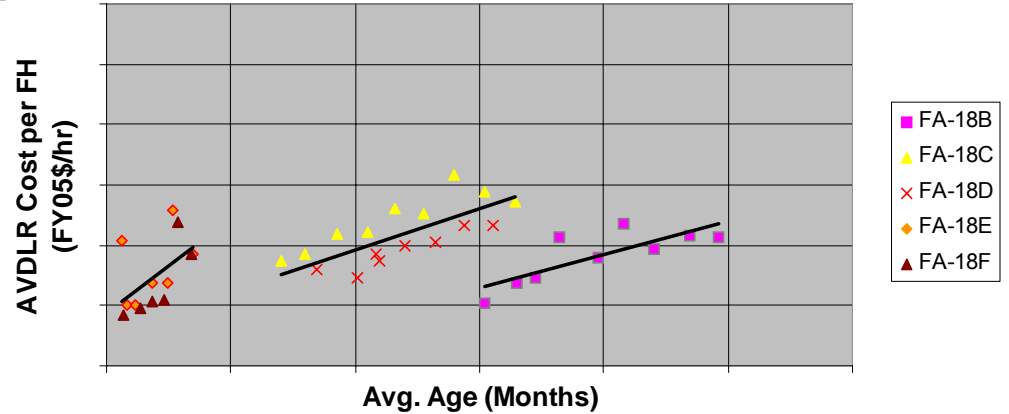
AVDLRs

AVDLR cost is patterned similarly to Consumables cost

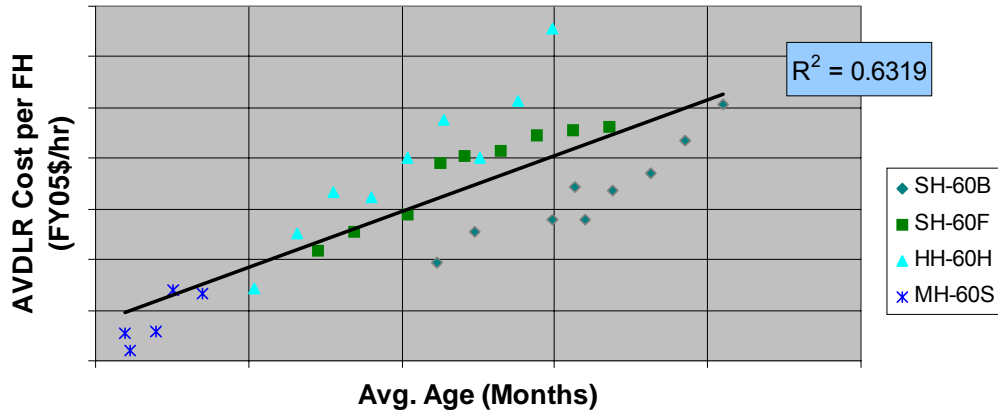
**AVDLR Cost per FH vs. Avg Age
(Fixed Wing A/C)**



**AVDLR Cost per FH vs. Avg Age
(F/A-18s)**



**AVDLR Cost per FH vs. Avg Age
(Rotary Wing A/C)**



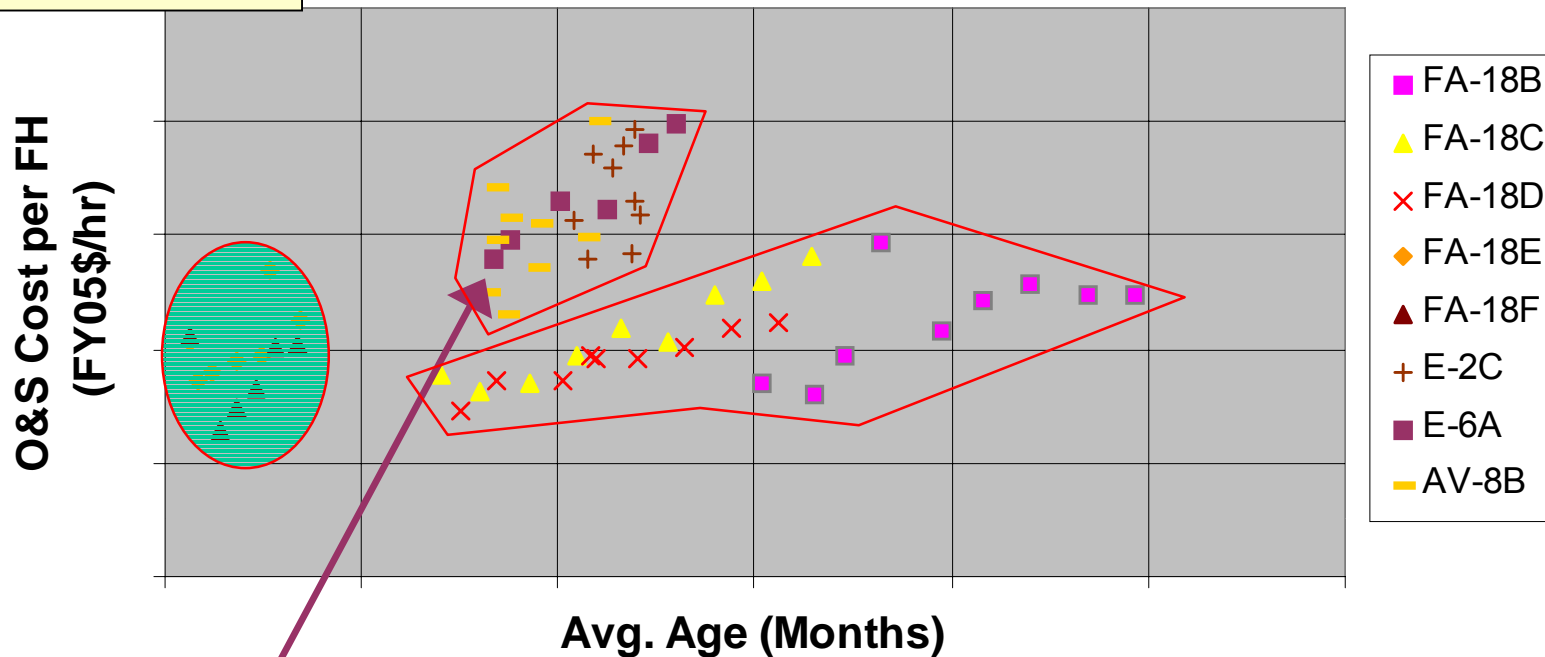
AVDLRs

- **From the graphs on the previous slide it's apparent that AVDLRs also have a linear relationship with age.**
 - This is appropriate for the same reason that the linear cost and age relationship for Consumables is appropriate.

Total O&S – Fixed Wing A/C

Notice the groupings of aircraft. It suggests there is another factor at play here.

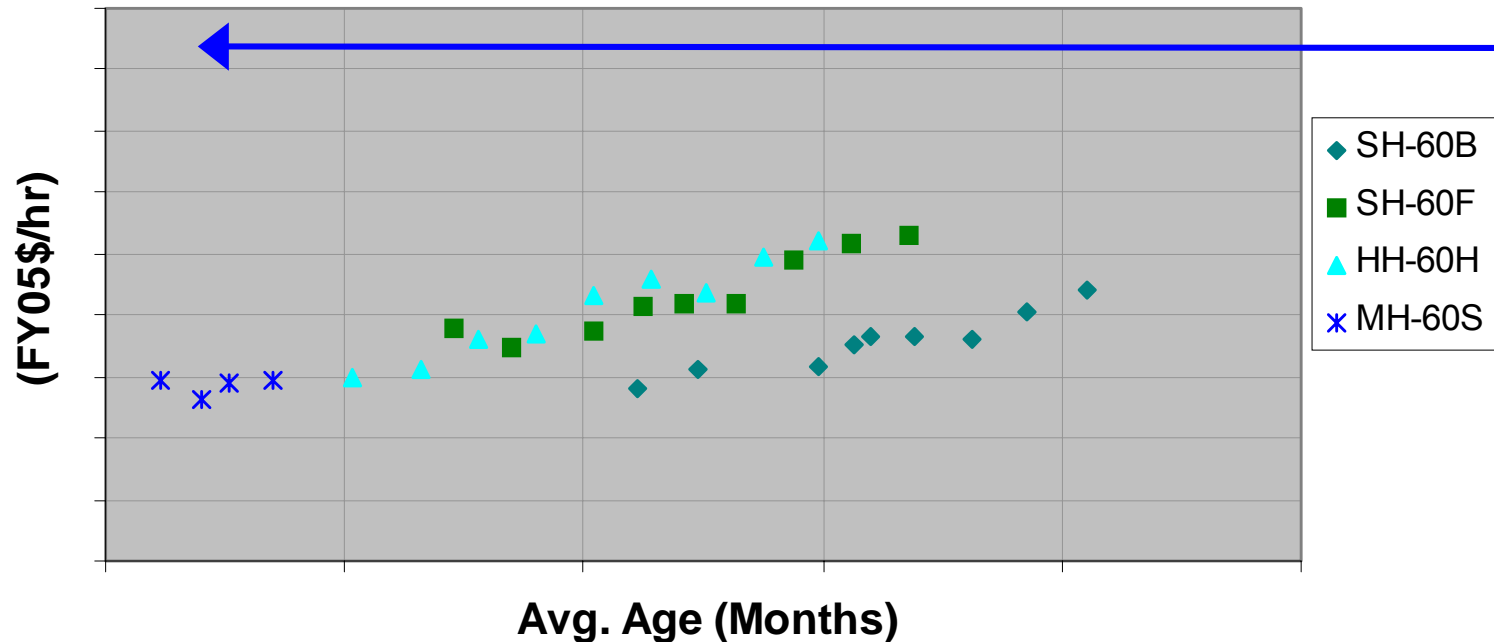
O&S Cost per FH vs. Avg Age (Fixed Wing A/C)



The E-6A had lower AVDLR and Consumables cost than the E-2C and AV-8B but has comparable total O&S cost per flight hour. This is due to the fact that the E-6A had considerably higher fuel costs (it is very heavy and built for endurance) and modernization costs.

Total O&S – Rotary Wing A/C

O&S Cost per FH vs. Avg Age (Rotary Wing A/C)



The H-60 aircraft continue to follow the same pattern we've seen in Consumables and AVDLR costs. The earliest MH-60S data point is very high due to large manning costs in it's first year of operation.

Summary of Aircraft Age Effects

- **Flight hours are not the only parameter to affect aircraft O&S cost.**
 - While flight hours are a main cost driver, the cost per flight hour is driven by other factors which need to be taken into account.
- **The age of an aircraft does impact it's O&S cost, whether it's fixed wing or rotary wing.**
 - Other factors may be impacting cost as well, but were not the focus of this study.
- **A positive linear relationship between cost and age is appropriate.**
 - This is not what was originally anticipated, but makes sense given the nature of aircraft.

Future Research

- **Additional research needs to be done into other factors that may be impacting fixed-wing costs.**
 - The F/A-18s would be a good place to start because they are variations of the same aircraft.
 - For the purposes of predicting cost for a new aircraft, recommend determining the most similar T/M/S and adjusting the CER as necessary.
- **Additional rotary wing aircraft other than just the H-60 family should be included in the analysis to determine if other factors are at play in rotary wing costs as well.**
- **Examine other cost elements for age effects.**
 - Consumables and AVDLRs were the focus of this research because if age effects appeared anywhere it seemed they would be most likely be found in these 2 elements.

Conclusions

The Big Picture

- **Age effects do exist.**
- **Just because age effects are understood for one platform does not mean that the same effect applies to other platforms.**
 - The relationship between cost and age could be different (linear, polynomial, power curve, etc.).
 - Different types of cost elements may be affected from platform to platform.
 - Different parameters may interact with age to provide the best CER (e.g. aircraft cost is affected by flight hours, but ship cost is not affected by steaming hours).
- **Incorporating age into the estimating process allows the program to have a more accurate picture of how much money needs to be spent and when.**
 - This is critical to the budgeting process!