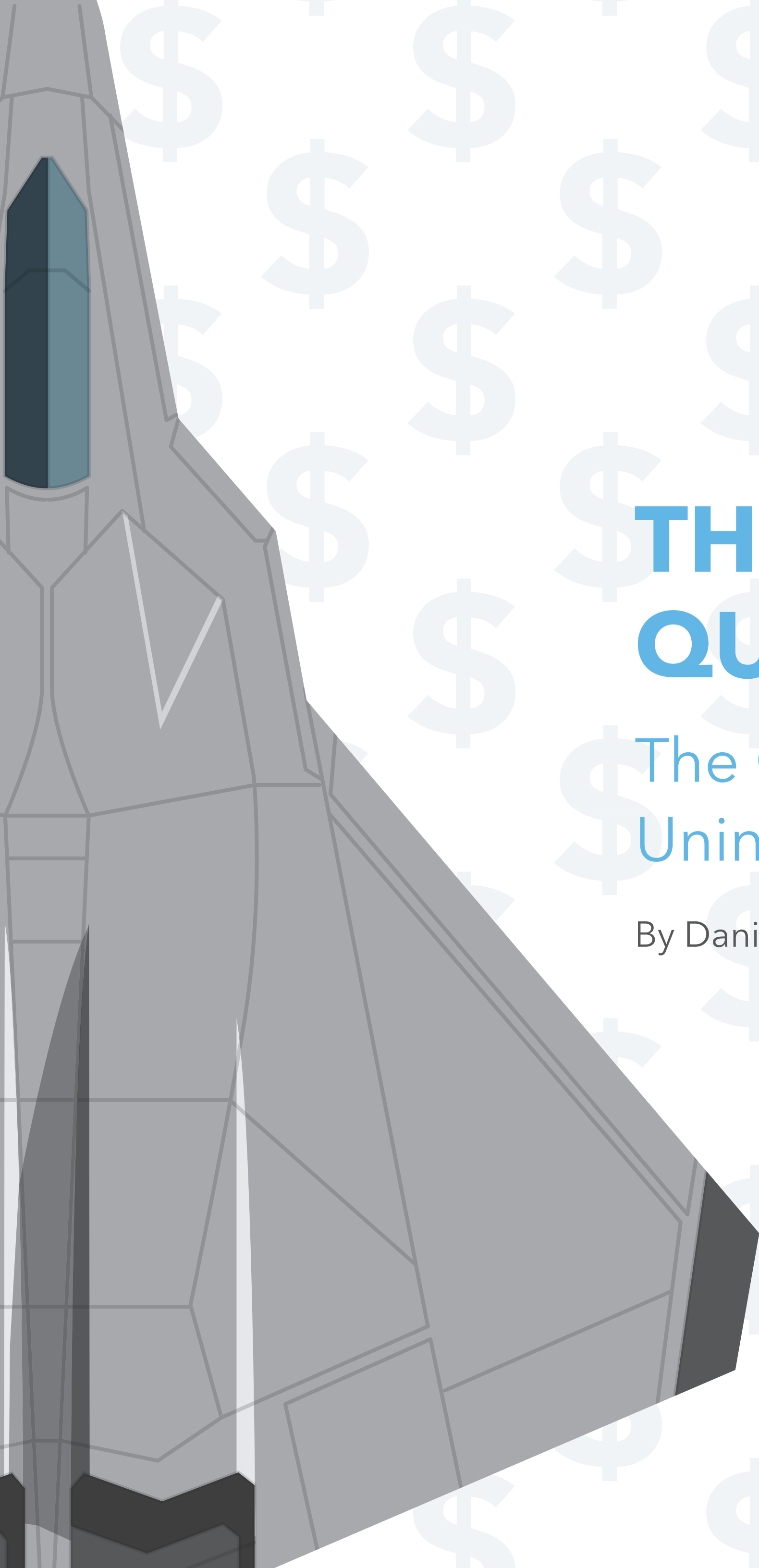
20YY SERIES | AUGUST 2015



THE $100 BILLION QUESTION:

The Cost Case for Naval Uninhabited Combat Aircraft

By Daniel Burg and Paul Scharre

Center for a New American Security

About the Authors

Daniel Burg is an Adjunct Senior Fellow at the Center for a New American Security (CNAS).
Paul Scharre is a Senior Fellow and Director of the 20YY Warfare Initiative at CNAS.

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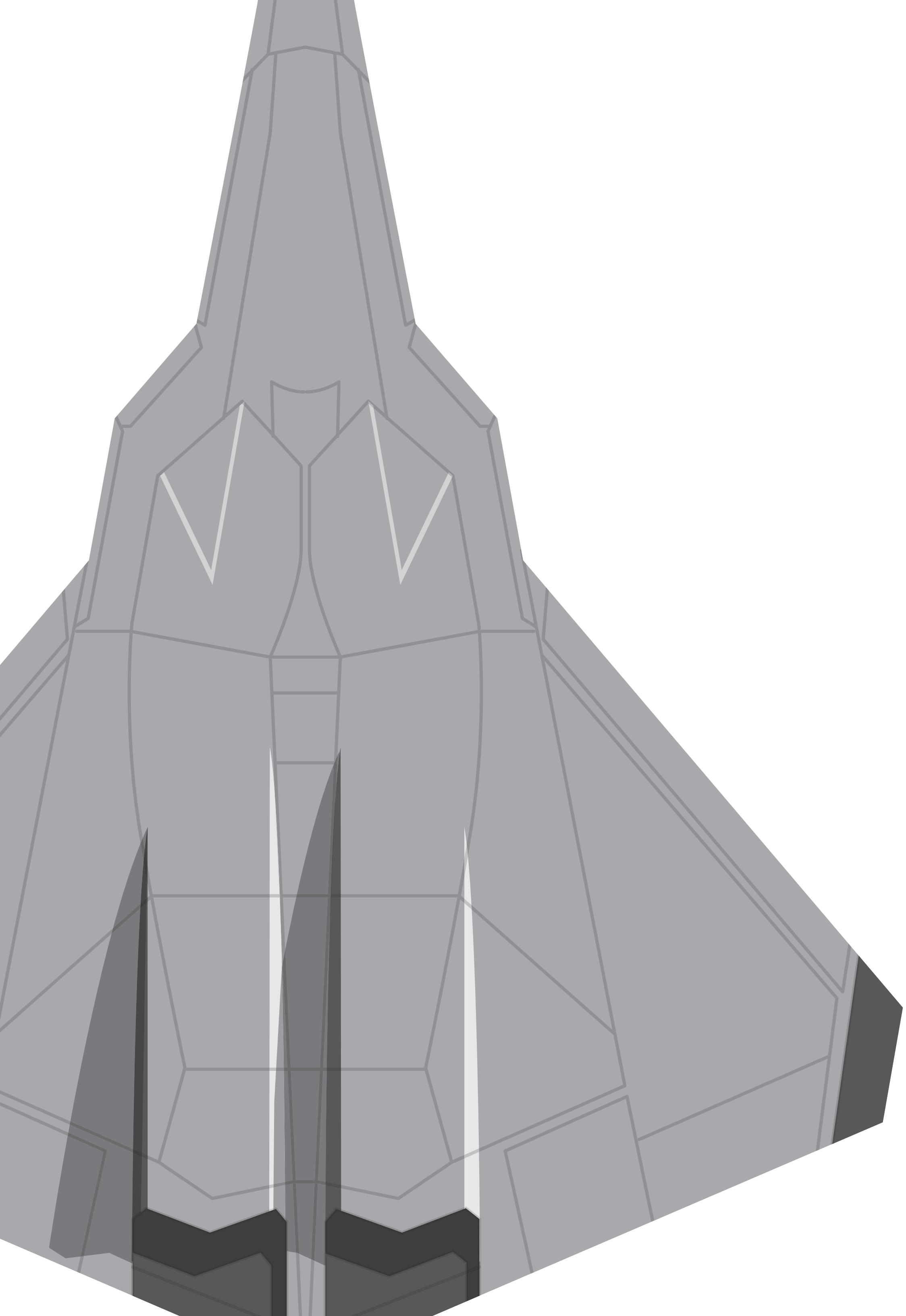
Acknowledgements

We would like to thank the many individuals in the Department of Defense and at CNAS who provided valuable feedback on this report. In particular, we would like to thank Melody Cook for the design of this report, Maura McCarthy for the editing, and NAV for their work on the illustrations. CNAS does not take institutional positions.



THE $100 BILLION QUESTION:

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EXECUTIVE SUMMARY

- The Navy is already beginning to examine options to replace the F/A-18E/F Super Hornet, which will retire in the mid-2030s.
- The replacement of the F/A-18E/F with a future naval aircraft (FNA) represents a major opportunity to shape the Navy's future carrier air wing to respond to emerging challenges but must take into account budget constraints.
- This analysis examines the potential cost differences in a notional human-inhabited ("manned") FNA compared to an uninhabited ("unmanned") FNA using three cases (conservative, moderate, and aggressive).
- All cases are structured to support the Navy's current Optimized Fleet Response Plan, which calls for two deployed carrier strike groups at all times, with the ability to temporarily surge up to six carriers.
- All uninhabited aircraft cases generate major cost savings, achieved by avoiding the costs of recurring pilot training.
    - » Because the uninhabited aircraft software flies the aircraft, costly flying hours are not needed to train pilots to control the aircraft and maintain their skills. The aircraft flies itself, with the remote pilot ("operator") in a decision-maker role, providing mission-level command.
    - » With fewer hours flying, fewer aircraft are needed.

Range of Potential Savings

(range depends on cost estimates for FNA)

WE ASSESS THE MINIMUM COST AVOIDANCE AT ABOUT $30 BILLION OVER 30 YEARS, WITH A MORE LIKELY COST AVOIDANCE IN EXCESS OF $100 BILLION.

Conservative Case	**$30B – $54B**
Moderate Case	**$80B – $140B**
Aggressive Case	**$95B – $170B**

- Because the cost of FNA is not yet known, we use a parametric cost model to examine a range of possible costs, depending on assumptions regarding cost of a next-generation aircraft.
- The Navy can achieve this cost avoidance only by replacing manned aircraft with uninhabited aircraft.
- These substantial savings could then be re-invested into other Navy priorities, such as additional ships, submarines, or other aircraft programs.
- These savings do not include real and highly substantial funds that could be saved by reductions in the initial pilot training infrastructure and supporting depot infrastructure.
- This is a “think piece” with many simplifying assumptions and is intended to illustrate the principles of what is different with uninhabited aircraft.

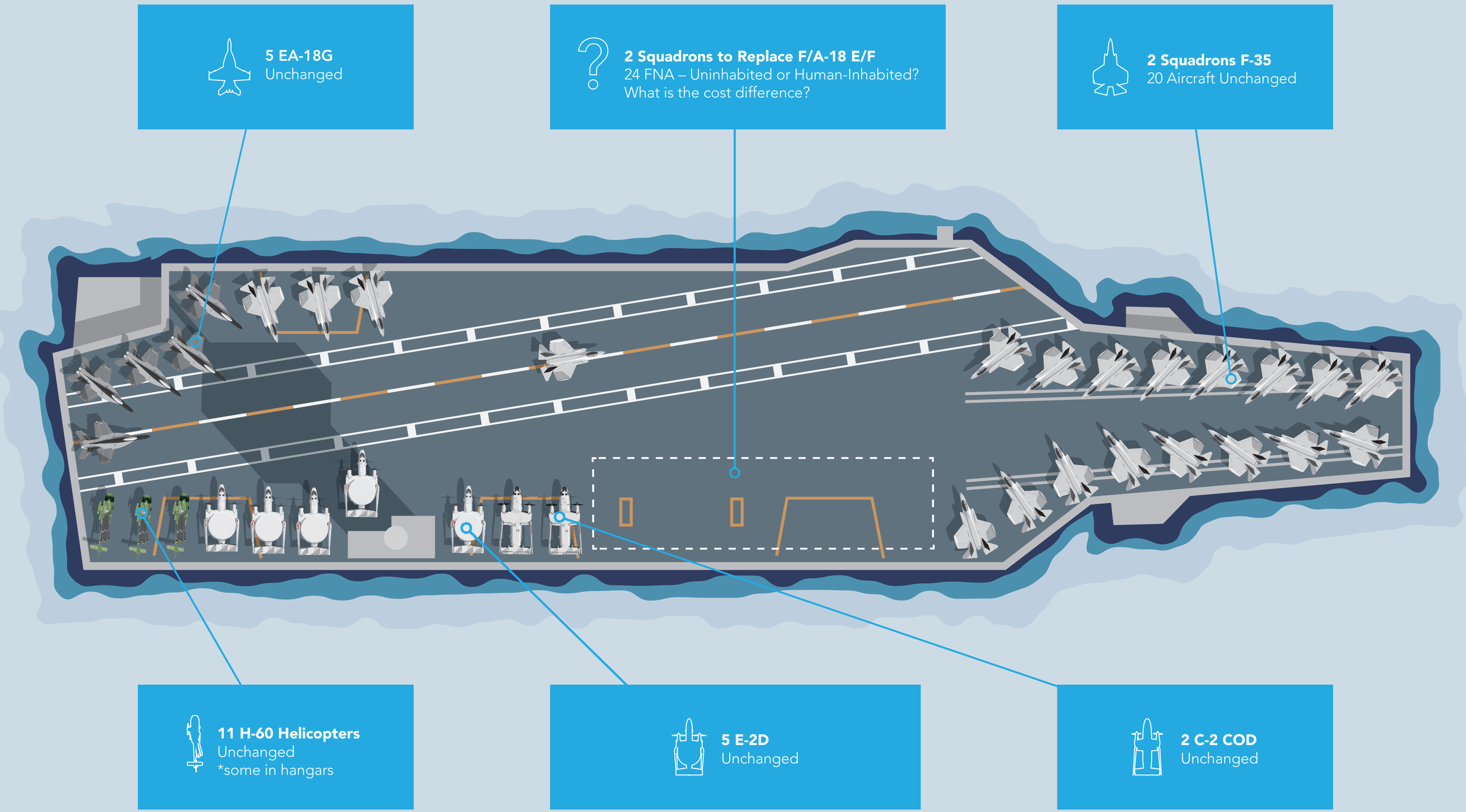
INTRODUCTION

The Navy is already beginning to examine options to replace the F/A-18E/F Super Hornet, which will retire in the mid-2030s.

The replacement of the F/A-18E/F with a future naval aircraft (FNA) represents a major opportunity to shape the Navy's future carrier air wing to respond to emerging challenges but must take into account budget constraints.

This analysis examines the potential cost differences between a notional human-inhabited FNA and an uninhabited FNA.

- This analysis isolates cost issues alone. It assumes that technology has matured to the point where an uninhabited aircraft with a high degree of autonomy and communications links to human operators would be at least equal in capability to a human-inhabited aircraft.
- Uninhabited aircraft also have significant operational advantages over human-inhabited aircraft due to their ability to operate beyond the endurance limits of human pilots, which this analysis does not include.


5 EA-18G
Unchanged
2 Squadrons to Replace F/A-18 E/F
24 FNA – Uninhabited or Human-Inhabited?
What is the cost difference?
2 Squadrons F-35
20 Aircraft Unchanged
11 H-60 Helicopters
Unchanged
*some in hangars
5 E-2D
Unchanged
2 C-2 COD
Unchanged

- The U.S. carrier fleet is trained and organized for two readiness objectives:
    - To generate continuously a certain number of deployed carrier groups – currently two carrier strike groups.
    - To generate temporarily a larger surge deployment capability – up to six carrier strike groups.
- Each alternative force examined must yield sufficient aircraft, including training, depot, and attrition aircraft, to meet both the steady-state (two carriers) and temporary surge (six carriers) requirements.

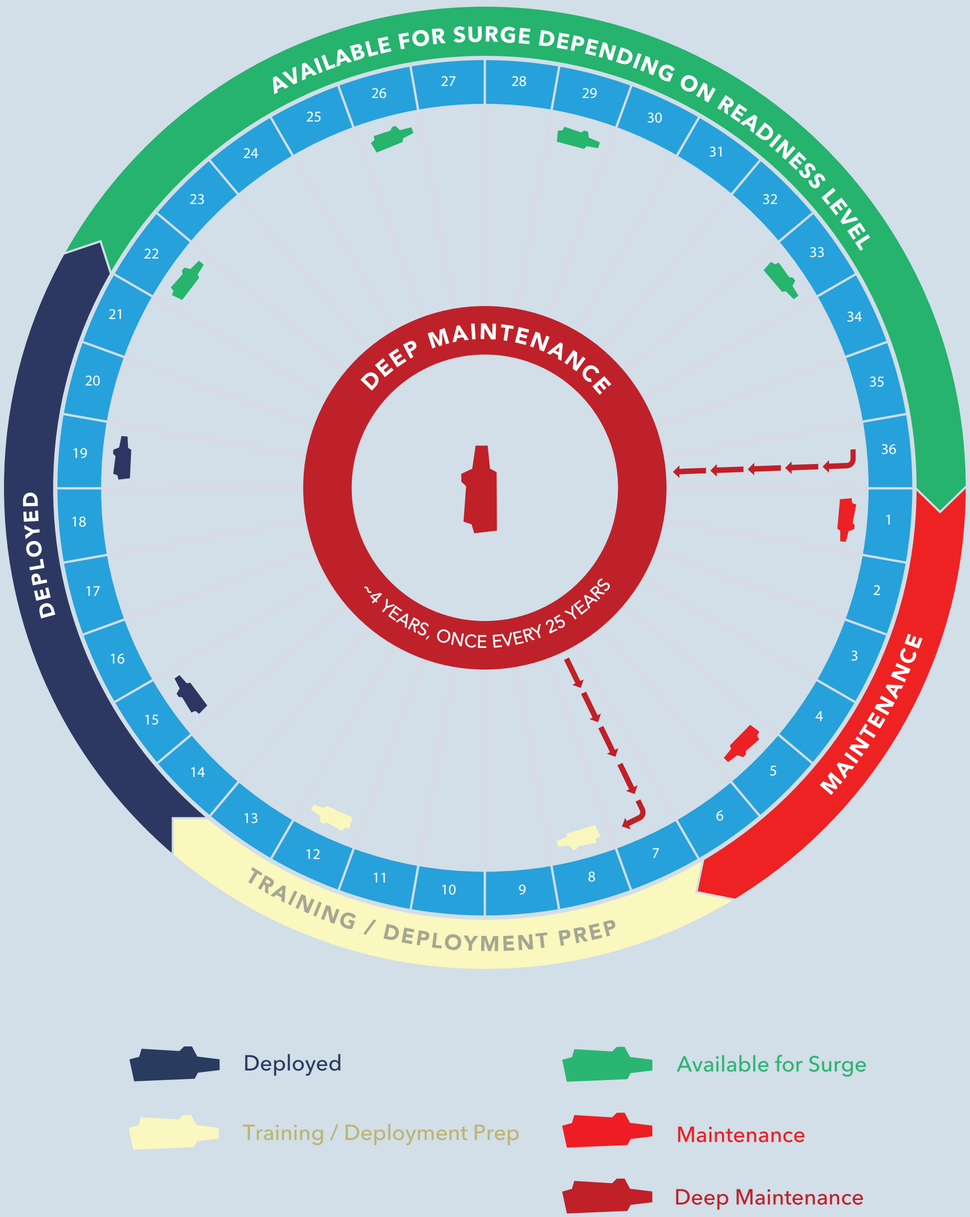
The Navy has 11 aircraft carriers, supporting 10 carrier strike groups.[1]

The carriers rotate through a regular 36-month readiness cycle, moving through periods of maintenance, pre-deployment preparation, deployment, and then a lengthy sustainment period where they are available for surge, as needed.

At 25 years, a carrier needs to enter deep maintenance for a refueling and complex overhaul of its nuclear reactor, a process which takes approximately four years.

Under the Navy's new Optimized Fleet Response Plan, at any given point in time there are roughly two carriers deployed, four available for surge, two in maintenance, two preparing for another deployment, and one in deep maintenance.[2]

36 Month Optimized Fleet Response Plan Cycle

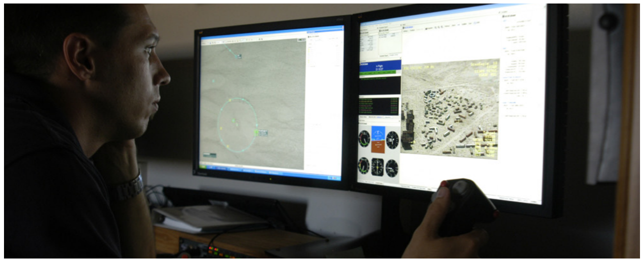


WHAT'S DIFFERENT FOR UNINHABITED AIRCRAFT?

First-generation uninhabited air vehicles (UAVs) were remotely controlled by a pilot on the ground, but newer UAVs are highly automated. Remote pilots ("operators") command the aircraft and tell it where to go, and the aircraft flies itself.

Human-Inhabited Aircraft

- Onboard pilots directly control the plane.
- Flying skills reside in the pilot.
- Each pilot must be trained individually.
- Pilot skills degrade over time. Large amounts of flying hours are needed to retain currency.
- Simulators are useful, but for a pilot who will sit in the plane there is no substitute for hands-on, in-the-cockpit experience.



Highly Automated UAVs

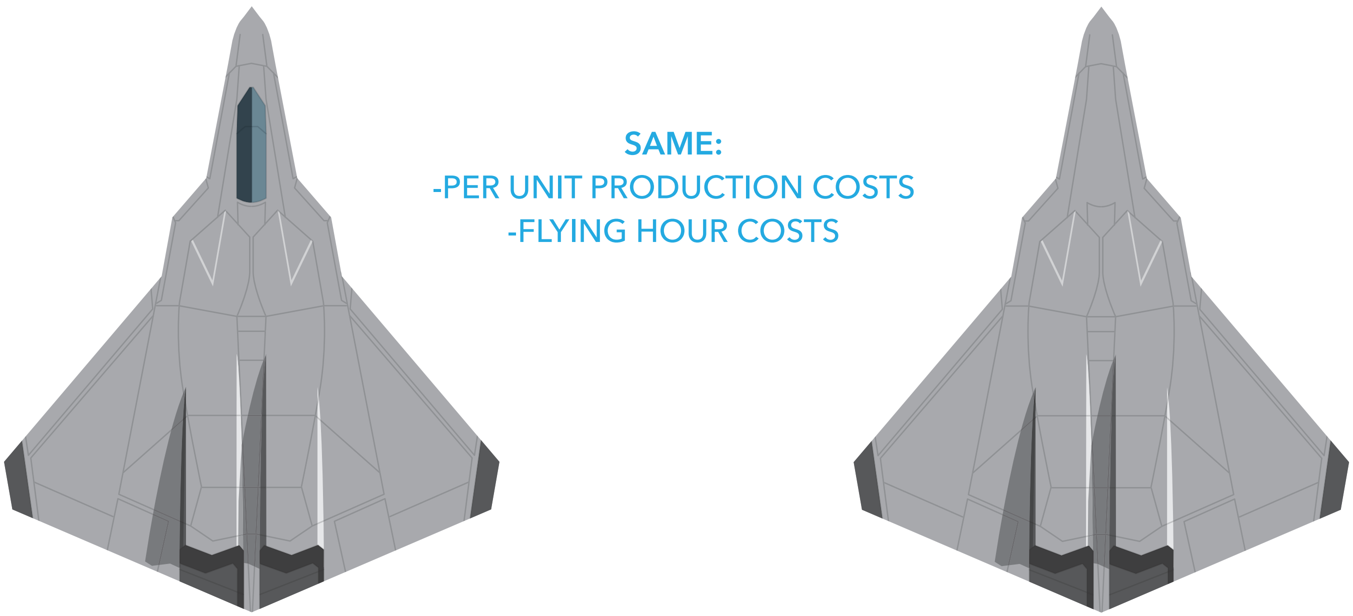
- Remote pilots/operators command the UAV at the mission level. Using onboard software, the UAV flies itself.
- Flying skills reside in the UAV's software. Remote pilots/operators are decision-makers.
- All UAVs are equally skilled and capable the moment they are completed.
- UAV skills don't improve or degrade over time. No additional flying hours are needed.
- No difference from the operator's perspective between a simulator and actual flying. The aircraft ground control station is the simulator.

Q: Wouldn't automated carrier takeoff and landing on human-inhabited aircraft allow these same savings?

A: Perhaps, but only if the Navy were willing to forgo training its pilots to manually land their aircraft on a carrier (which is still the quintessential distinguishing requirement for a Navy pilot), allowing a reduction in training flight hours. Even still, for a pilot who will physically sit in the aircraft, there is no substitute for actual flying.

Cost Differences Between Inhabited and Uninhabited Aircraft

We assume that cost differences unique to human-inhabited vs. uninhabited aircraft variants are sufficiently small that they can be excluded.

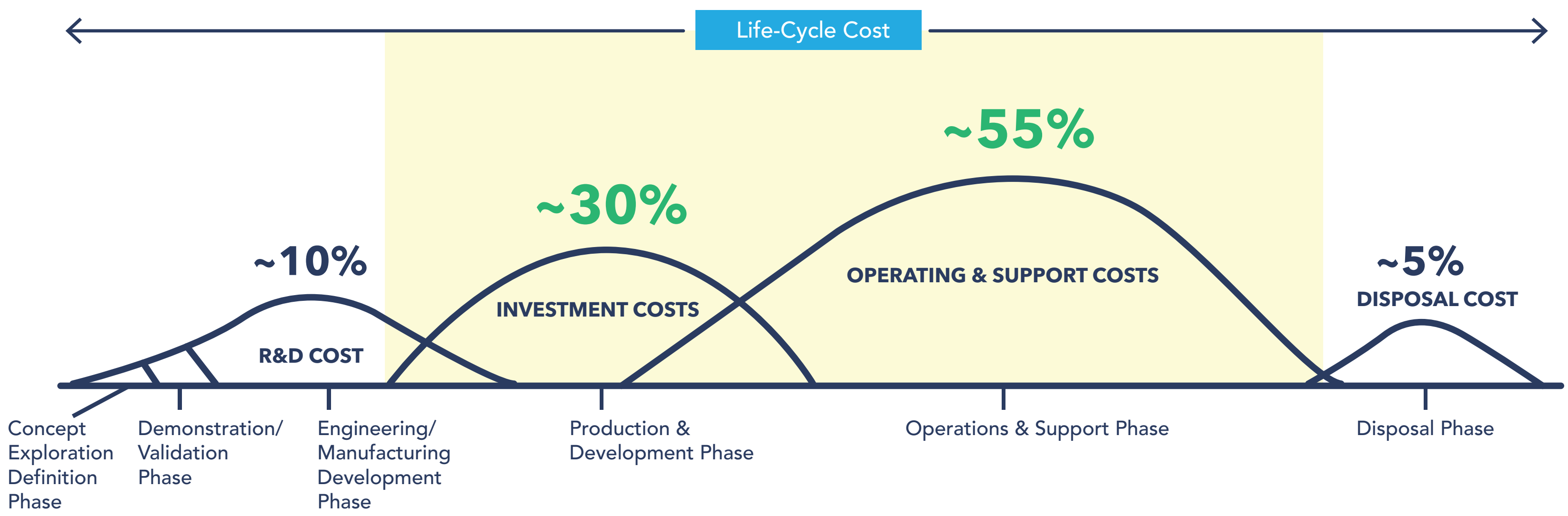


DIFFERENCES IN LIFE-CYCLE COST WILL THEREFORE BE DRIVEN BY:

1. The number of aircraft purchased, and
2. The way these aircraft are operated.

AIRCRAFT LIFE-CYCLE COSTS

Total costs throughout an aircraft program consist of research and development (R&D), investment (aircraft production), operating and support (O&S), and disposal. Since R&D costs are driven primarily by mission requirements, which would be the same for both aircraft variants, this study will focus on investment costs and operating and support costs.



Life-Cycle Cost Differences

COST CATEGORY	DIFFERENCE BETWEEN INHABITED AND UNINHABITED AIRCRAFT	TREATMENT IN STUDY
Research and Development (R&D)	Marginal difference	Excluded from study
Investment	May vary significantly depending on the number of aircraft purchased	Central to study
Operating and Support (O&S)	May vary significantly depending on the number of hours flown	Central to study
Disposal	Same cost per plane; small percentage of total cost	Excluded from study

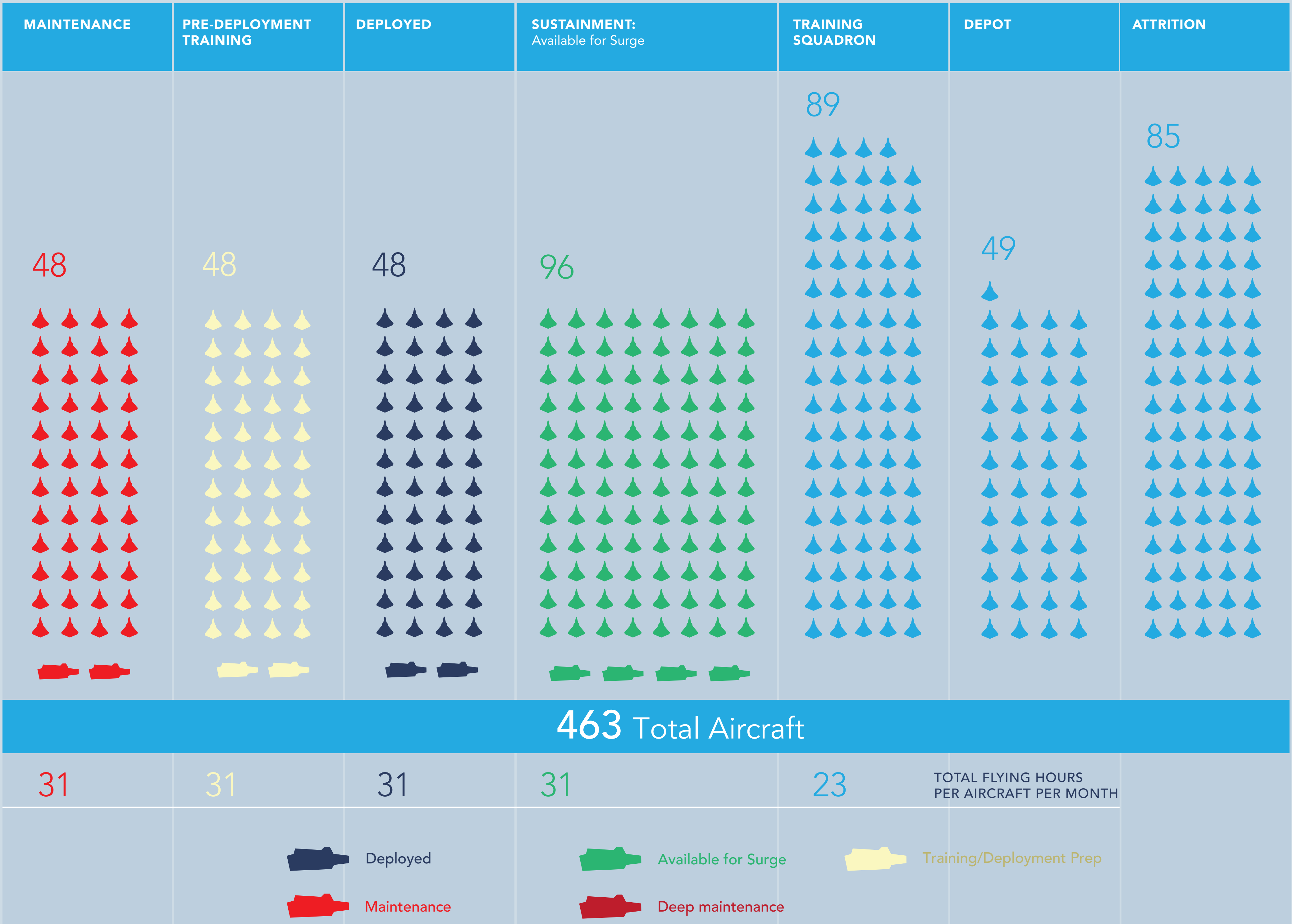
HUMAN-INHABITED FNA

First, we estimate the cost of a notional human-inhabited FNA as a base case. In order to meet the requirements of two carriers deployed steady-state and the ability to surge up to six, 463 total aircraft are needed.[3]

The number of aircraft is determined by:

- 24 aircraft per air wing for all 10 carrier air wings (carrier in deep maintenance does not require an air wing);
- 144 aircraft to meet six wing surge demand continuously present on carriers;
- Training squadron = 37% of carrier aircraft = 89 aircraft;[4]
- Aircraft at depot maintenance = 15% x (carrier + training aircraft) = 49 aircraft;[5]
- Attrition occurs at an average rate of three losses per 100K hours flown = 85 aircraft over a 25-year fleet service life;[6] and
- 31 flying hours per aircraft per month for aircraft in the 10 air wings; 23 flying hours per aircraft per month in the training squadron.[7]

HUMAN-INHABITED FNA



What Are all Those Planes For?

IF THE NAVY CARRIER FORCE IS DESIGNED TO SUPPORT, AT MOST, SIX CARRIERS DEPLOYED, WHY ARE THERE SO MANY PLANES ON CARRIERS THAT CAN'T BE DEPLOYED?

Two carriers are typically in a maintenance cycle.

The air wings are always off board conducting training.

Two carriers are typically in the "pre-deployment training" cycle of preparation.

The air wings are conducting training and are frequently off board.

Two carriers are typically deployed on forward station.

The air wings are on board the carrier conducting training or operations.

Four carriers are typically in the "sustainment" cycle of preparation.

The air wings are conducting training and are frequently off board.

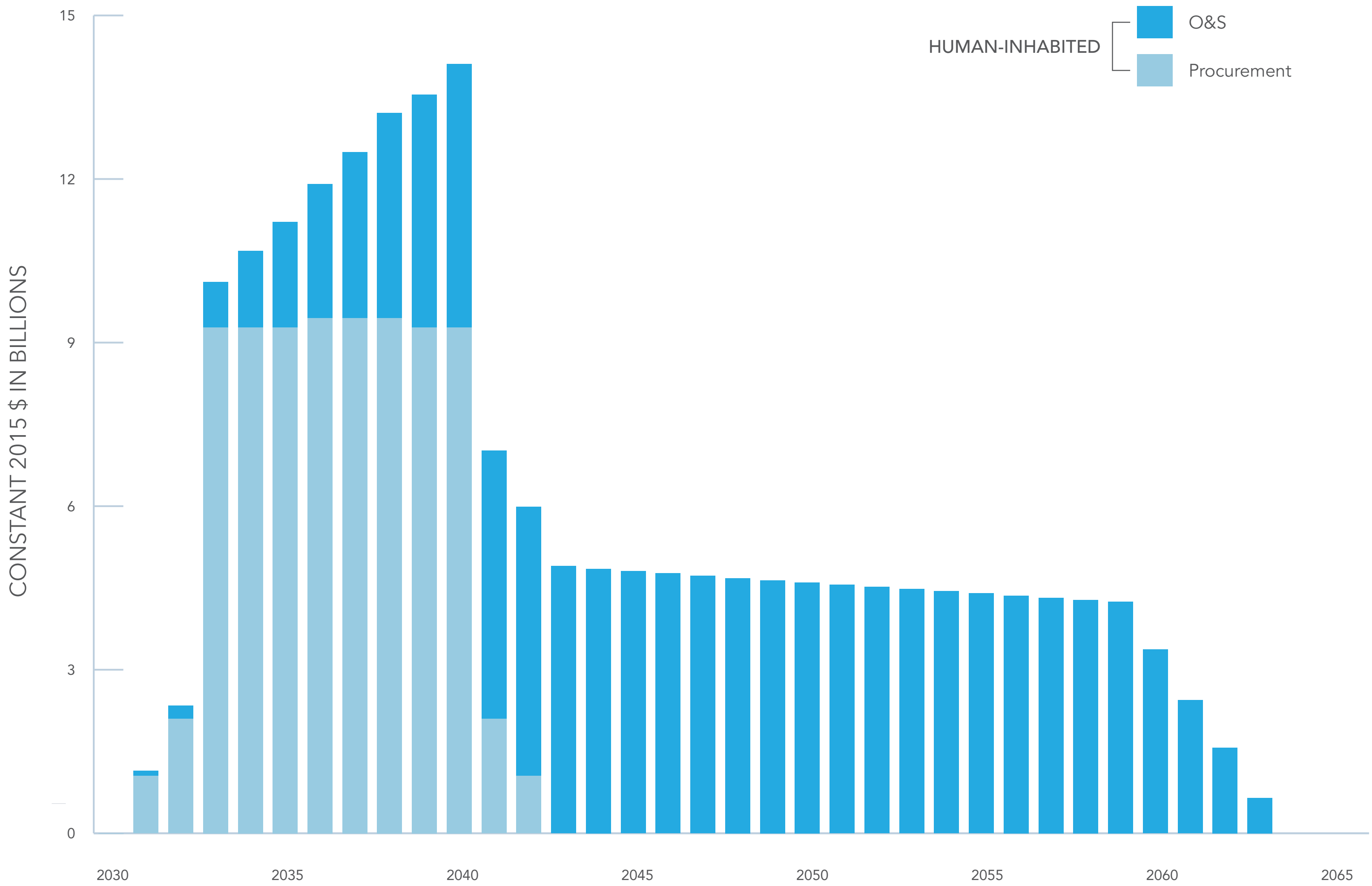
The training squadron, or "fleet replacement squadron," consists of shore based aircraft used for pilot, deck handler, and maintainer training.

Depot aircraft are generally in some form of higher level maintenance or modification.

Attrition aircraft are produced to compensate for anticipated losses.

WHAT DOES A MILITARY UNIT DO WHEN IT ISN'T AT WAR?
IT TRAINS. 10 AIR WINGS ARE NEEDED TO SUPPORT A SURGE OF 6 IN ORDER TO KEEP PILOT SKILLS CURRENT.

Human-Inhabited FNA Costs (modest cost increase)



- Excluding R&D and disposal costs, total program life-cycle costs will consist of the costs to procure the aircraft plus the O&S costs to operate and support them over a 25-year lifespan.[8]
- Since the precise costs of an FNA are not known, this analysis uses a parametric cost model, based on actual F/A-18E operating costs and anticipated F-35C costs.[9] Three cases are presented, representing a range of estimates for the anticipated increase in costs for a next-generation FNA relative to the F-35C:
  1. No increase in costs relative to the F-35C;
  2. A modest increase in costs relative to the F-35C; or
  3. A significant increase in costs relative to the F-35C, equivalent to the increase in costs from the F/A-18E to F-35C.
- Since the key variable is the **difference** between an uninhabited and a human-inhabited FNA, a rough order-of-magnitude estimate of FNA costs is sufficient to understand the potential for cost savings.

Range of Costs for Human-Inhabited FNA

	F/A-18E COSTS	FNA COSTS (No Cost Increase)	FNA COSTS (Modest Cost Increase)	FNA COSTS (Significant Cost Increase)
	Actual F/A-18E costs	If FNA costs equaled F-35C costs	If the cost increase from the F-35C to FNA were half as much as the cost increase from the F/A-18E to F-35C	If the cost increase from the F-35C to FNA were as much as the cost increase from the F/A-18E to F-35C
Number of Aircraft Procured	463	463	463	463
Unit Procurement Cost	$75 M	$130 M	$175 M	$220 M
Total Procurement Cost	$34.7 B	**$60.2 B**	**$81.0 B**	**$101.9 B**
Cost per Flying Hour	$15K/hr	$28K/hr	$39K/hr	$50K/hr
Total Operating and Support Cost	$45.5 B	**$84.9 B**	**$118.3 B**	**$151.7 B**
Total Program Life-Cycle Cost*	$80.2 B	**$145.1 B**	**$199.3 B**	**$253.6 B**

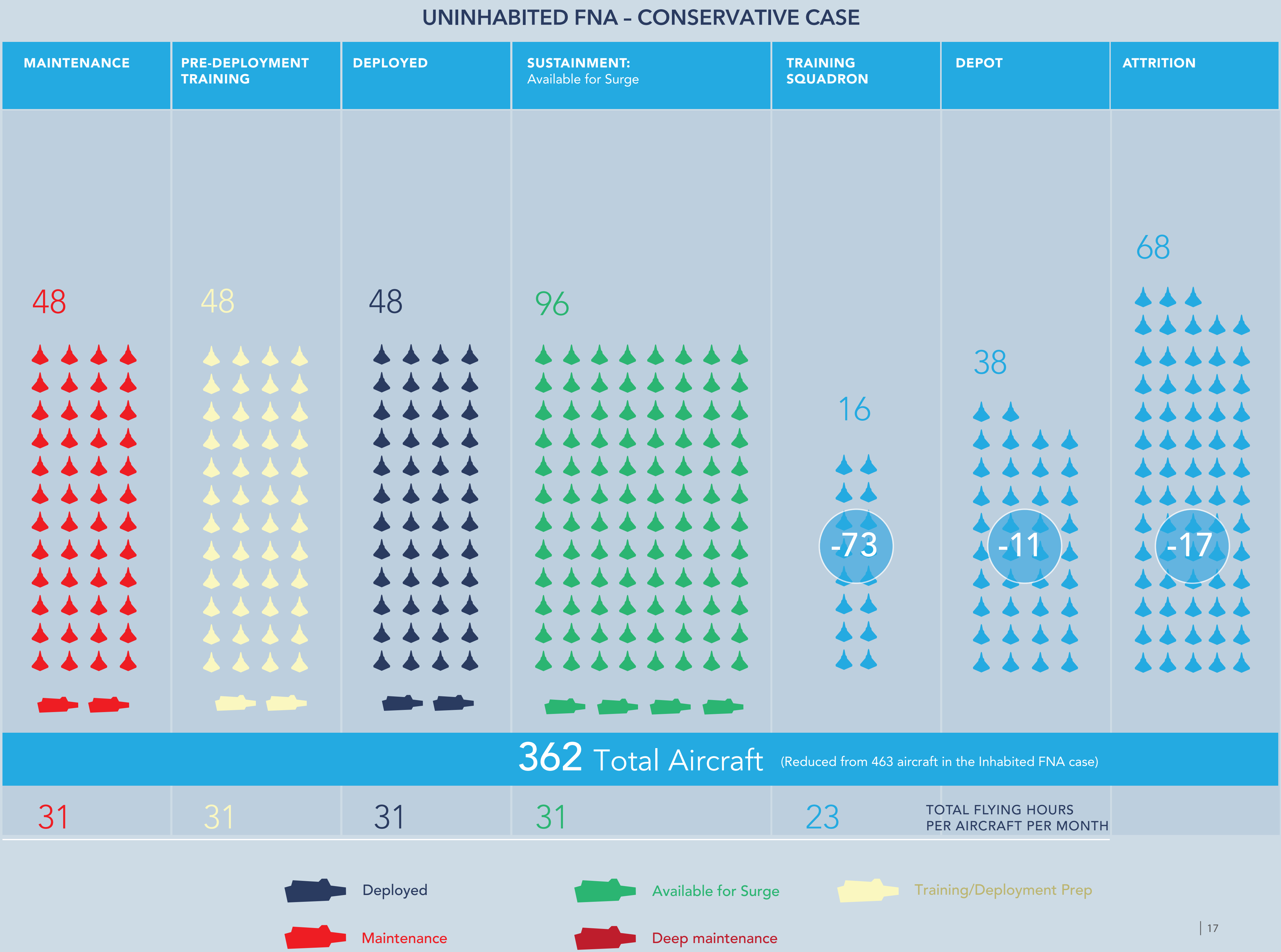
*Excludes R&D and disposal costs.

UNINHABITED FNA – CONSERVATIVE CASE

The conservative case estimates the cost savings from a single change: a reduction in the number of aircraft required in the training squadron. Because the UAV flies itself, remote pilots/operators do not need to train on aircraft handling skills. Moreover, because there is no "seat-of-the-pants" feel gained from flying the aircraft, a significant fraction of mission training can be done via simulator, reserving actual aircraft flying for final exercises.[10]

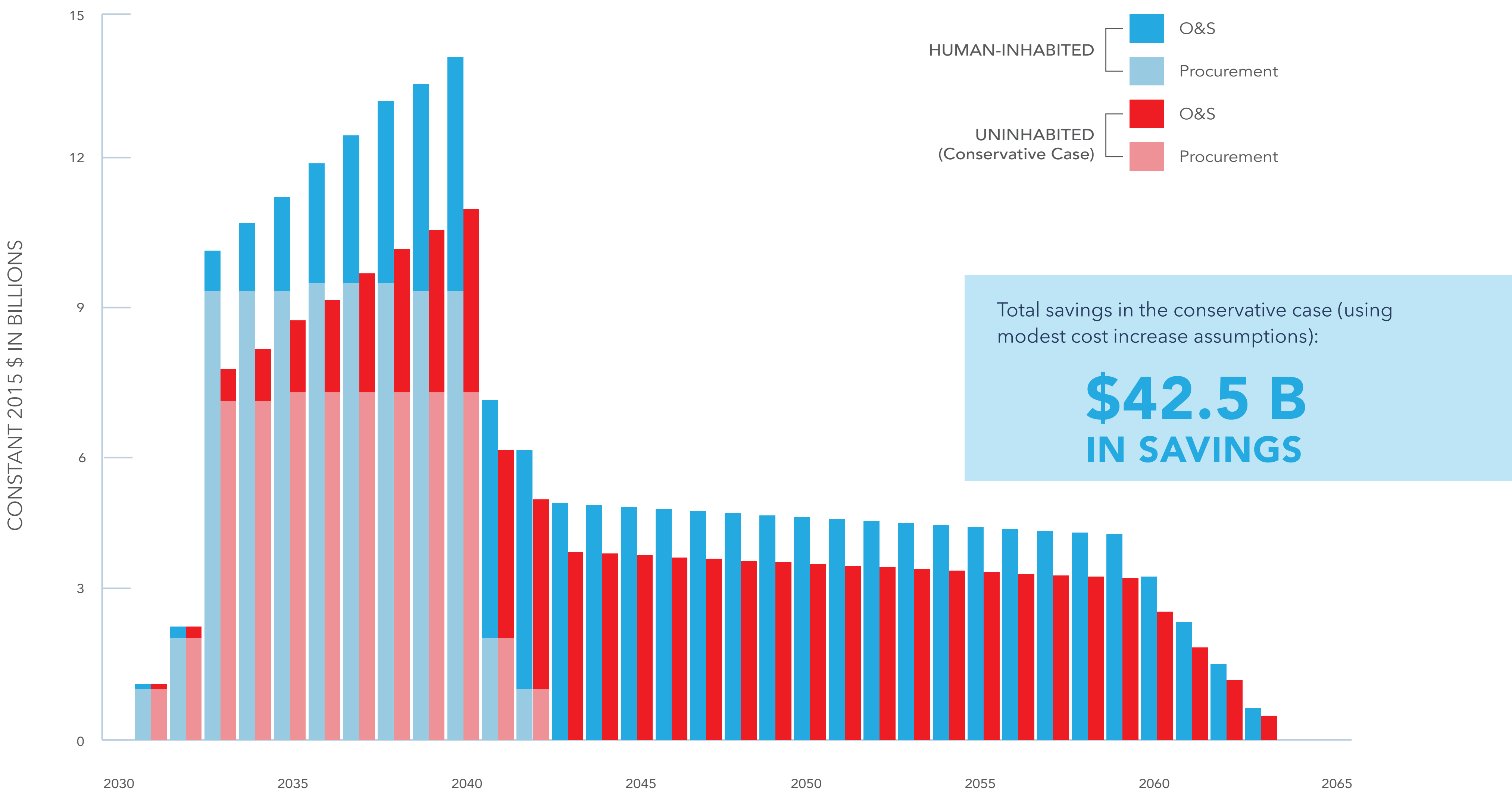
In the conservative case:

- Training aircraft are reduced to 16 aircraft. These are used for handler and maintainer training (who require hands-on experience with the aircraft) and squadron-level joint training exercises with manned aircraft.
- This results in a reduction in the number of aircraft at the depot.
- A reduced training squadron means fewer hours flown and a corresponding reduction in the number of attrition aircraft.[11]
- The number of aircraft allocated to each carrier air wing remains unchanged, as does the number of flying hours per month.
- 144 aircraft meets the six wing surge demand continuously present on carriers.



UNINHABITED FNA – CONSERVATIVE CASE
MAINTENANCE
PRE-DEPLOYMENT TRAINING
DEPLOYED
SUSTAINMENT: Available for Surge
TRAINING SQUADRON
DEPOT
ATTRITION
48
48
48
96
16
38
68
-73
-11
-17
362 Total Aircraft
(Reduced from 463 aircraft in the Inhabited FNA case)
31
31
31
31
23
TOTAL FLYING HOURS PER AIRCRAFT PER MONTH
Deployed
Available for Surge
Training/Deployment Prep
Maintenance
Deep maintenance

Uninhabited FNA – Conservative Case



Cost Comparison – Conservative Case

USING MODEST COST INCREASE ASSUMPTIONS	BASE CASE: HUMAN-INHABITED FNA	UNINHABITED FNA – CONSERVATIVE CASE	SAVINGS
Number of Aircraft Procured	463	362	
Unit Procurement Cost	$175 M	$175 M	
Total Procurement Cost	**$81.0 B**	**$63.4 B**	**$17.6 B**
Cost per Flying Hour	$39K/hr	$39K/hr	
Total Operating and Support Cost	**$118.3 B**	**$93.4 B**	**$24.9 B**
Total Program Life-Cycle Cost*	**$199.3 B**	**$156.8 B**	**$42.5 B**

*Excludes R&D and disposal costs.

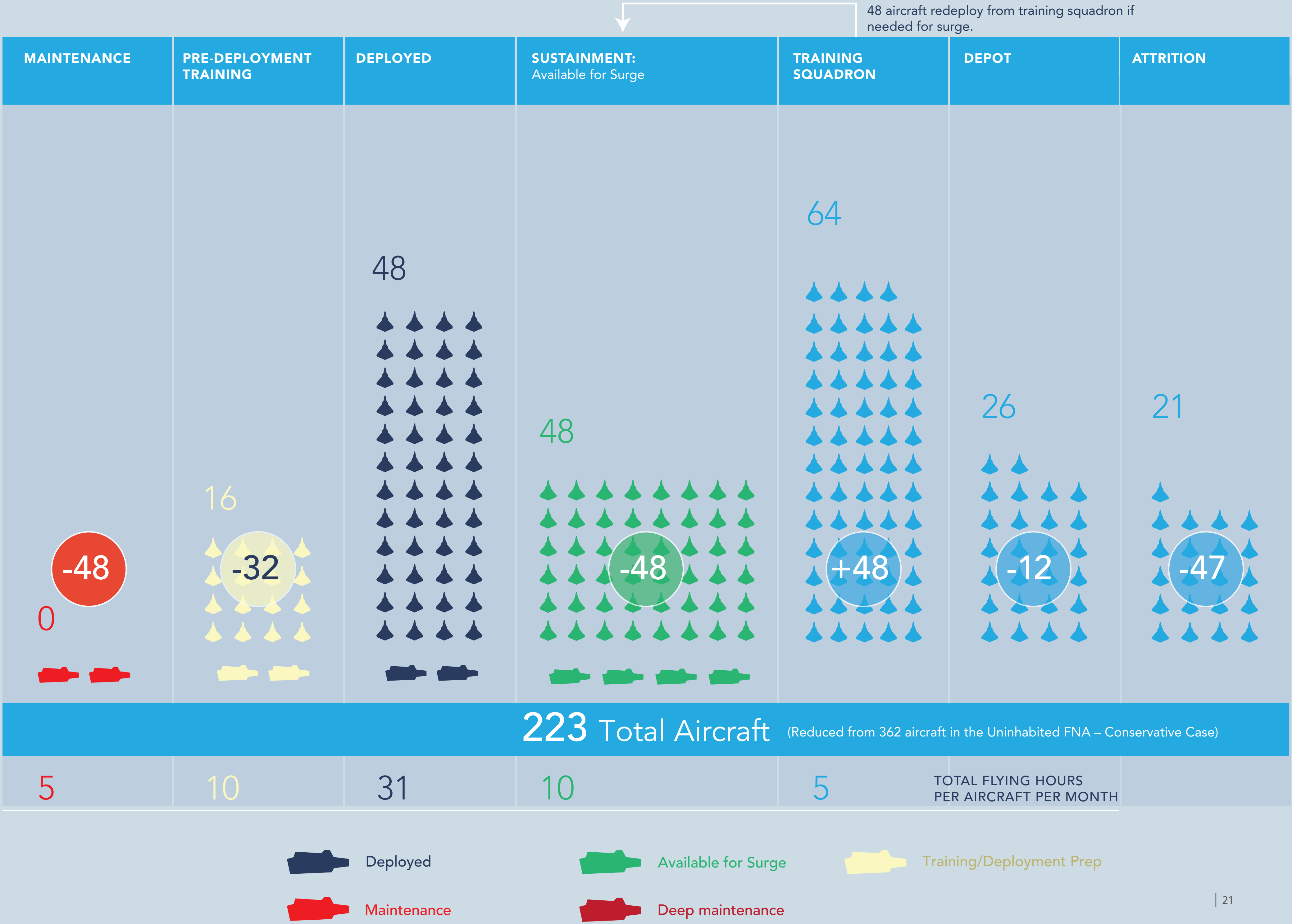
UNINHABITED FNA – MODERATE CASE

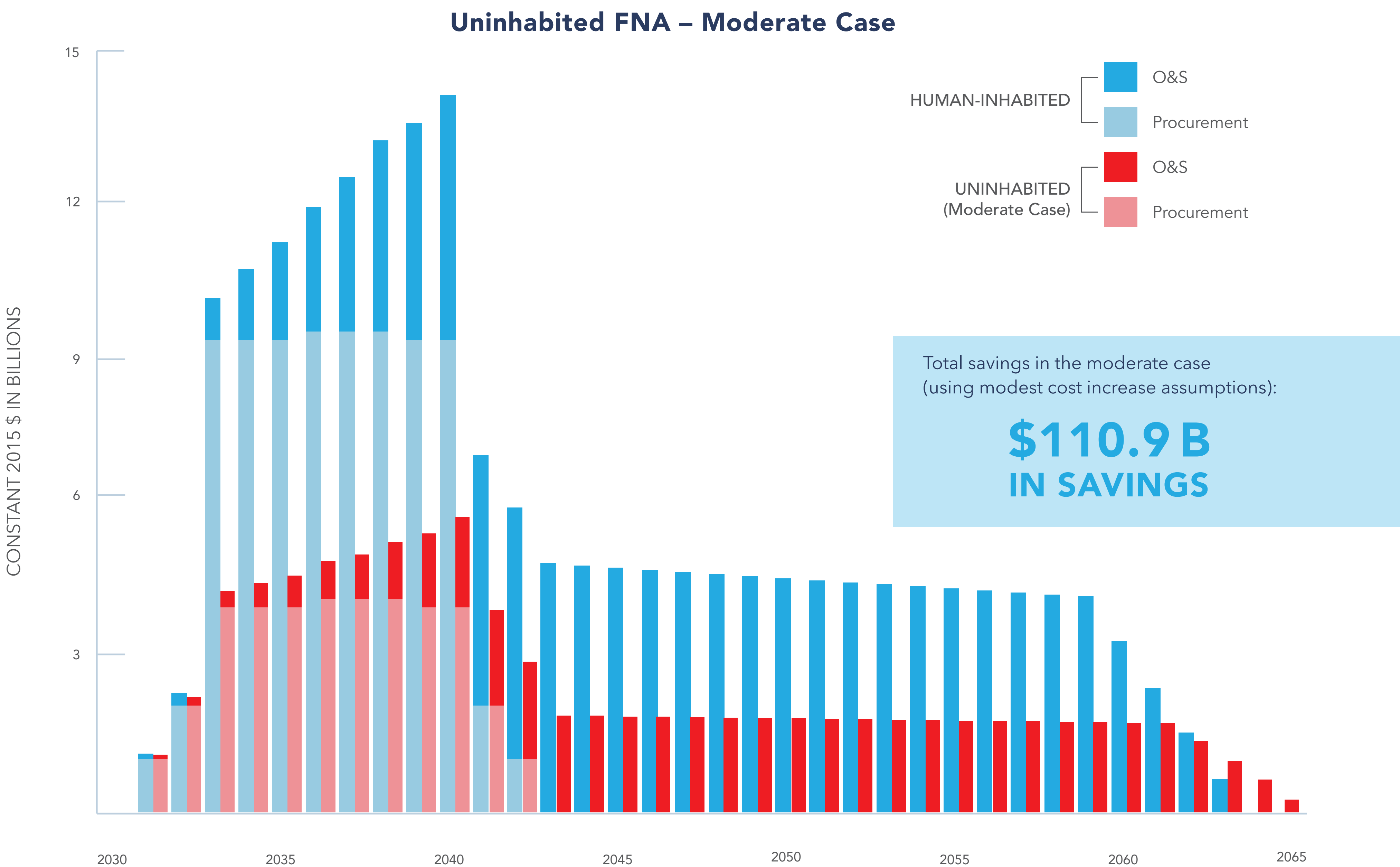
The moderate case capitalizes even further on the advantages of uninhabited aircraft. Just as the number of aircraft needed for initial training can be reduced, so too can the number of aircraft needed for currency training in the non-deployed air wings. In addition, flying hours can be reduced in the non-deployed air wings. This approach takes inspiration from the Navy's current practice of "cross-decking" aircraft between carriers to cover shortfalls.

In the moderate case:

- Eliminate squadrons associated with the carriers in the maintenance phase, since they are used exclusively for pilot training. Maintain deployed strength by "cross-decking" aircraft between carriers.
- Reduce the air wings associated with the carriers in phase training, leaving only an eight aircraft contingent to exercise the deck crew and maintenance personnel.
- Except for the carrier in sustainment that is most ready to deploy, position the majority of sustainment aircraft ashore in the training squadron. This enhances aircraft readiness and reduces operating costs, and these aircraft can transition back to the carriers for surge deployment very quickly if needed.
- 144 aircraft meets the six wing surge demand: 48 in deployed wings, +48 in sustainment wings, +48 in training squadron
- Reduce flying hours for non-deployed air wings to 10 hours per aircraft per month. Reduce flying hours for training squadron aircraft to five hours per aircraft per month.[12] These changes lead to corresponding reductions in depot and attrition aircraft. With fewer aircraft flying and reduced flying hours per aircraft, the number of aircraft lost to attrition is substantially reduced.

UNINHABITED FNA – MODERATE CASE




Uninhabited FNA – Moderate Case
HUMAN-INHABITED
O&S
Procurement
UNINHABITED (Moderate Case)
O&S
Procurement
Total savings in the moderate case (using modest cost increase assumptions):
$110.9 B IN SAVINGS
CONSTANT 2015 $ IN BILLIONS
15
12
9
6
3
2030
2035
2040
2045
2050
2055
2060
2065

Cost Comparison – Moderate Case

USING MODEST COST INCREASE ASSUMPTIONS	BASE CASE: HUMAN-INHABITED FNA	UNINHABITED FNA – MODERATE CASE	SAVINGS
Number of Aircraft Procured	463	223	
Unit Procurement Cost	$175 M	$175 M	
Total Procurement Cost	**$81.0 B**	**$39.0 B**	**$42.0 B**
Cost per Flying Hour	$39K/hr	$39K/hr	
Total Operating and Support Cost	**$118.3 B**	**$49.4 B**	**$68.9 B**
Total Program Life-Cycle Cost*	**$199.3 B**	**$88.4 B**	**$110.9 B**

*Excludes R&D and disposal costs.

Is it Wise to Reduce Uninhabited Aircraft from 10 to 6 Air Wings?

WHY 10?

Non-deployed aircraft hedge against risk in "extreme" scenarios, e.g. catastrophic loss of deployed carriers and/or air wings.

Makes it possible to surge all 10 carriers into a fight.

WHY 6?

The probability of such extreme scenarios is low. Accepting this kind of unlikely risk means the funding can be redirected to other priorities, which already have higher risk.

The Fleet Response Plan requires at most a six carrier surge capability. That's because the fleet cannot sustain more than six carriers on station, and even six is problematic for any length of time.

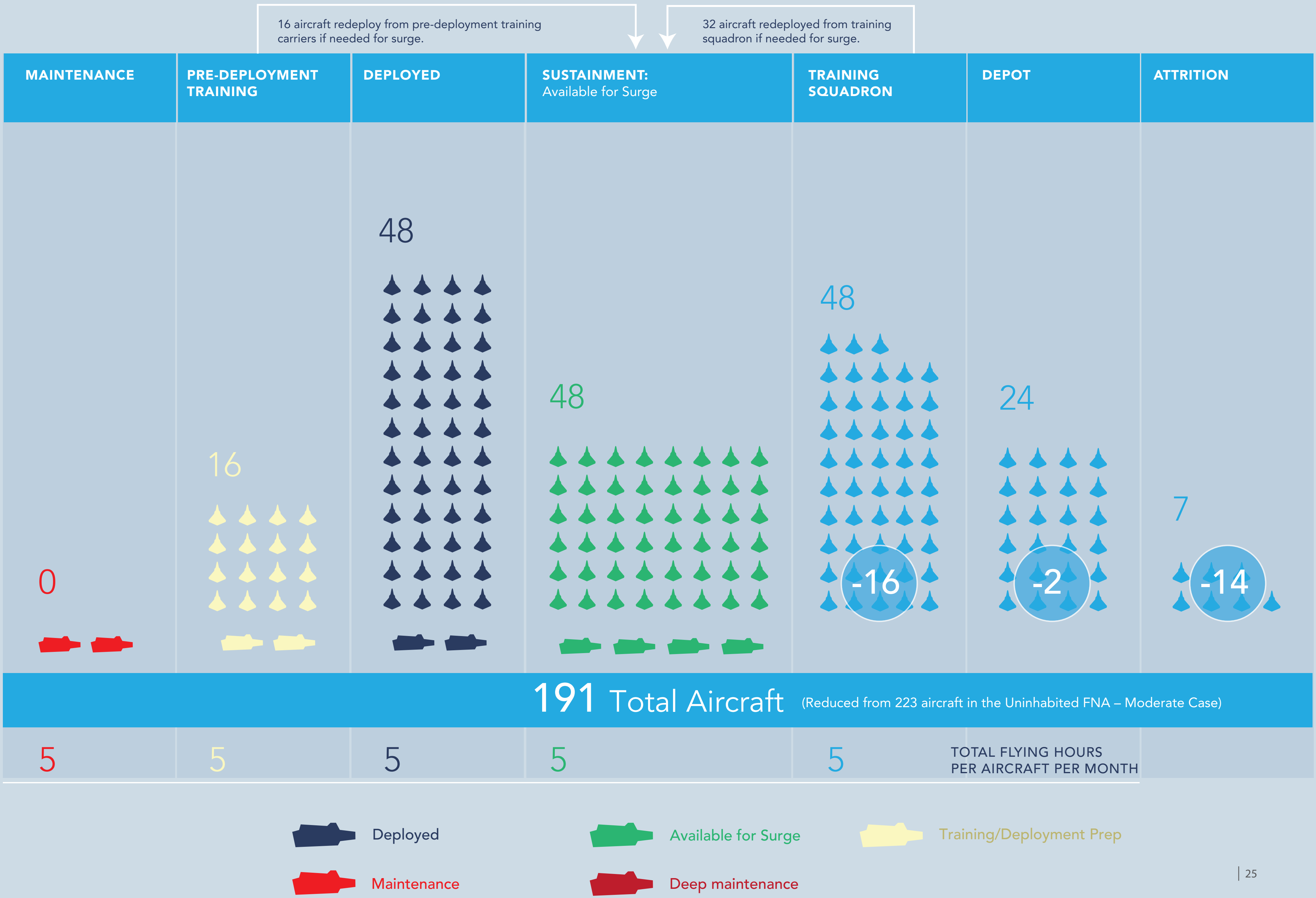
UNINHABITED FNA – AGGRESSIVE CASE

The aggressive case seeks to find the outer boundary of possible savings. It reduces the number of aircraft procured to the absolute minimum and assumes a peacetime operating tempo.

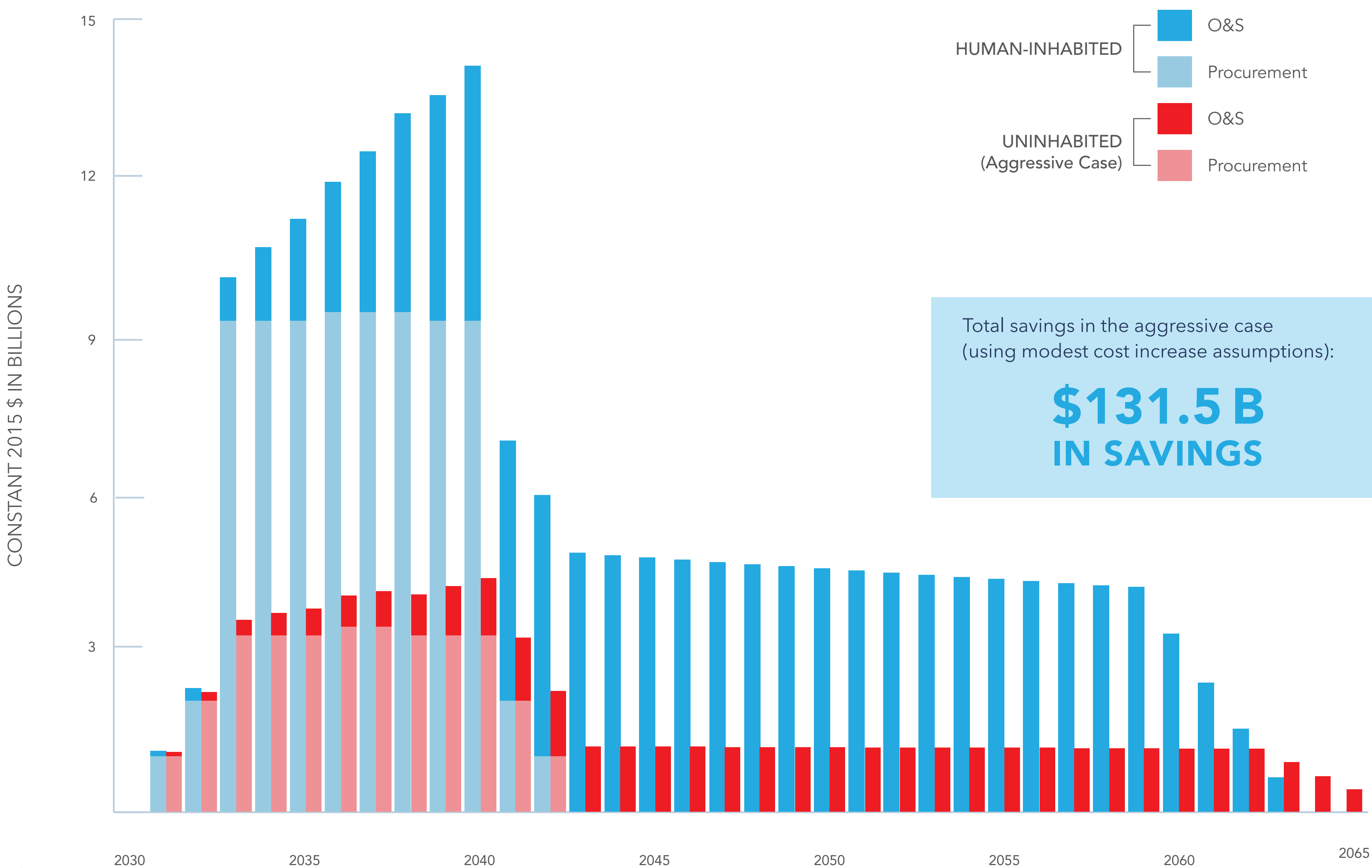
In the aggressive case:

- Redeployment of the pre-deployment training aircraft fleshes out the surge, allowing 16 aircraft to be reduced from the training squadron. In a six carrier surge, the 32 other required surge aircraft would come from the training squadron, leaving 16 aircraft to continue training. This modestly reduces overhead at the depot.
- 144 aircraft meets the six wing surge demand: 48 in deployed wings, +48 in sustainment wings, +16 in pre-deployment wings, +32 from training squadron
- Flying hours in all phases is reduced to the minimum necessary to exercise the aircraft and maintain its mechanical assurance: five hours per aircraft per month. This allows a significant reduction in attrition aircraft.

UNINHABITED FNA – AGGRESSIVE CASE



Uninhabited FNA – Aggressive Case



Total savings in the aggressive case
(using modest cost increase assumptions):

$131.5 B
IN SAVINGS

Cost Comparison – Aggressive Case

USING MODEST COST INCREASE ASSUMPTIONS	BASE CASE: HUMAN-INHABITED FNA	UNINHABITED FNA – AGGRESSIVE CASE	SAVINGS
Number of Aircraft Procured	463	191	
Unit Procurement Cost	$175 M	$175 M	
Total Procurement Cost	**$81.0 B**	**$33.4 B**	**$47.6 B**
Cost per Flying Hour	$39K/hr	$39K/hr	
Total Operating and Support Cost	**$118.3 B**	**$34.4 B**	**$83.9 B**
Total Program Life-Cycle Cost*	**$199.3 B**	**$67.8 B**	**$131.5 B**

*Excludes R&D and disposal costs.

TOTAL ESTIMATED SAVINGS

Using the parametric cost model to account for a range of possible FNA costs in terms of aircraft per-unit costs and flying hour costs, we can arrive at a range of estimated cost savings for each case.

	UNINHABITED FNA – CONSERVATIVE CASE	UNINHABITED FNA – MODERATE CASE	UNINHABITED FNA – AGGRESSIVE CASE
Number of aircraft (a/c) procured (base case = 463)	362	223	191
Assuming no cost increase ($130M per a/c, $28K / flying hr)[13]	**$31.0 B**	**$80.7 B**	**$95.7 B**
Assuming modest cost increase ($175M per a/c, $39K / flying hr)	**$42.5 B**	**$110.9 B**	**$131.5 B**
Assuming significant cost increase ($220M per a/c, $50K / flying hr)[14]	**$54.2 B**	**$141.1 B**	**$167.7 B**

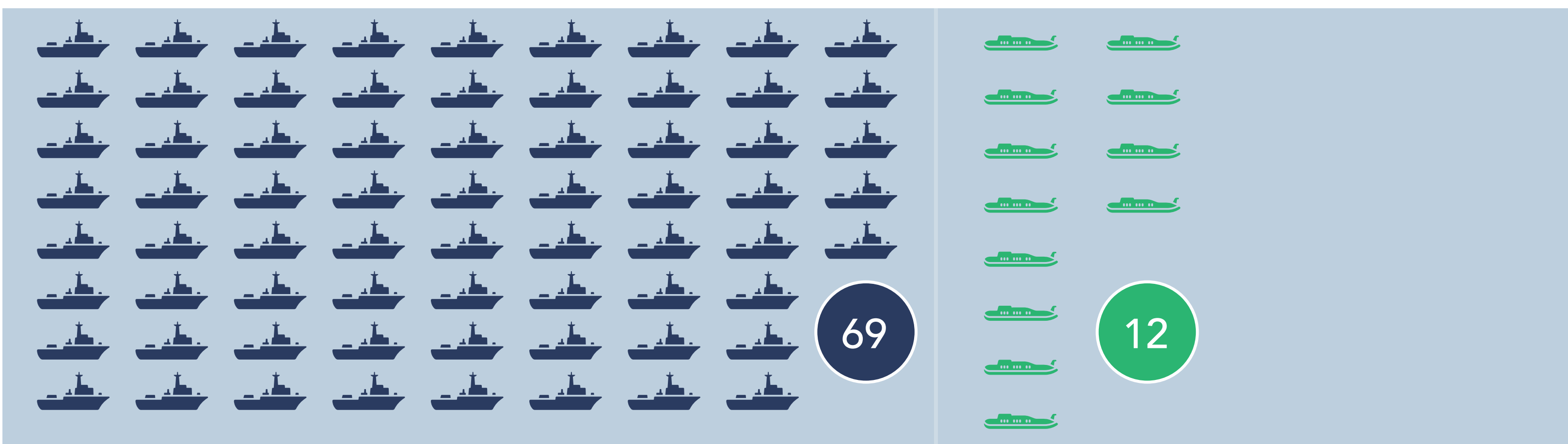
Additional savings not captured:

- In the moderate and aggressive cases, reduced flying hours per month results in the aircraft reaching the end of their lifespan with significant flying hours remaining. These aircraft could then be used for other purposes, such as combat attrition (without needing additional pilots). Or they could be used to extend the service life of the aircraft but without a costly service life extension program.
- Savings in reduced depot infrastructure.
- Savings in reductions in initial phases of pilot training (including basic flight training aircraft and flying hours).[15]

CONCLUSIONS

- An uninhabited FNA offers significant life-cycle cost savings over a human-inhabited FNA.
- We assess the minimum cost avoidance of more than $30 billion over 30 years, with a more likely cost avoidance in excess of $100 billion.
    - » Some fraction of these savings could potentially be achieved in a highly automated human-inhabited FNA if the Navy were to forgo training pilots to land their aircraft manually. Even still, a large fraction of normal in-the-cockpit flying would be needed to maintain other mission skills, leading to higher costs than an uninhabited version.
- The savings achieved by investing in an uninhabited FNA could be reinvested into other Navy priorities, such as additional ships, submarines, or other aircraft programs.

***ARLEIGH BURKE*-CLASS DESTROYERS** -OR-	***OHIO*-CLASS BALLISTIC MISSILE SUBMARINE REPLACEMENT**
For example, $110 billion in cost savings would allow the Navy to purchase an additional 69 *Arleigh Burke*-class destroyers.[16]	Alternatively, $110 billion could fund the entire *Ohio*-class ballistic missile submarine replacement program (SSBN(X)).[17]



ENDNOTES

1. With the retirement of the USS *Enterprise* (CVN-65) in 2012, the Navy currently has only 10 carriers in the fleet. Provided the Navy overhauls the USS *George Washington* (CVN-73) at its scheduled 25-year refueling and complex overhaul, the number of carriers will return to 11 when the USS *Gerald R. Ford* (CVN-78) enters service in 2016. The Navy has a statutory requirement under Section 1011(a) of the FY2007 National Defense Authorization Act to maintain no less than 11 operational carriers. The Navy is currently operating under a temporary waiver from Congress, authorized in the FY2010 National Defense Authorization Act, to operate 10 carriers until CVN-78 is commissioned. For additional background, see Ronald O'Rourke, *Navy Ford (CVN-78) Class Aircraft Carrier Program: Background and Issues for Congress*, Congressional Research Service, Washington, DC, June 12, 2015.
2. Admiral Bill Gortney, USN, "Navy Optimized Fleet Response Plan" (26th Annual Surface Navy Association National Symposium, Crystal City, VA, January 2015).
3. As of 2015, the Navy program for F/A-18E/F is 563 aircraft. This actual program number differs from the "steady state ideal" number (463) for potentially a number of reasons. The most likely reason is that the F-35C is perhaps not being produced as quickly or at as great a rate as would be ideal for the air wing, especially given the additional flying hours on the F/A-18E/Fs from supporting operations in Iraq and Afghanistan. This means that greater numbers of E/F models are needed to compensate for shortfalls. The steady state number also does not account for the (relatively minor) effects of aircraft being introduced into the air wing over time, as opposed to an instantaneous total quantity delivery.
4. Derived from Navy Visibility and Management of Operating and Support Costs (VAMOSC) data. Since the actual number of aircraft in the training squadron ("fleet replacement squadron") varies over time, 37% is a representative mid-range value.
5. Actual number of aircraft in depot maintenance varies over time. 15% is a representative figure. Since the same depot percentage is used for all cases, however, a slightly higher or lower depot percentage would not significantly change the difference in costs between cases.
6. Based on F/A-18 Class A mishap rate, 1990 –2013. Edward Hobbs, "Comparison of Aviation Mishap Rates for Hornet Squadrons During Periods of Extended Reduced Flight Hours With Periods of Normal Flight Operations," Navy Safety Center, 9, http://www.public.navy.mil/comnavsafecen/Documents/statistics/ops_research/PDF/13-004.pdf.
7. Representative monthly flying hours, derived from VAMOSC data.
8. More precisely, we calculate the cost to procure and operate two squadrons per each of two deployed carriers for 25 years (= 100 "deployed squadron years") – along with all the other aircraft needed to sustain this deployed capability and a six air wing surge capability. This will take longer than 25 years since production takes more than a decade to complete; hence there will be a variable number of squadrons extant at any given time.
9. Costs calculated using the Navy's Operating and Support Cost Analysis Model (OSCAM).
10. This is how training is already done for highly automated UAVs like the RQ-4 Global Hawk, where 100 percent of flight control training and approximately 40 percent of mission training is performed via simulator, significantly reducing training flying hours. See Paul Scharre, "Can Automation Reduce Training Costs: A Preliminary Assessment Based on a Comparison Between U.S. Air Force Manned and Unmanned Aircraft Pilot Initial Qualification Training," Center for a New American Security, Washington, DC, October 13, 2014, http://www.cnas.org/sites/default/files/Scharre_Automation_Training_Costs_2014.pdf
11. This assumes that the attrition rate for the aircraft is equal. The human-inhabited and uninhabited FNA are assumed to be the same aircraft, except flight controls on the uninhabited FNA are automated. Just as autopilot functionality improves safety for commercial aircraft and automatic ground collision avoidance has saved military aircraft, under most conditions automated flight controls are likely to achieve better safety and reliability than human pilots.

12. Because in the moderate case some of the aircraft from the non-deployed air wings in sustainment are transferred to the training squadron, the total number of flying hours available to students drops only modestly relative to the conservative case. In the conservative case, 16 aircraft are available in the training squadron, each flying 23 hours per month, yielding a total of 368 flying hours per month available for training. In the moderate case, flying hours drops to five hours per aircraft per month, but 64 aircraft are available in the training squadron, yielding 320 flying hours available for student training per month.
13. Assuming no cost increase from the F-35C to FNA, total life-cycle costs, excluding R&D, for a human-inhabited FNA are $145.1B ($60.2B procurement and $85.0B O&S). Total life-cycle costs, excluding R&D, for an uninhabited FNA using the conservative case are $114.1B ($47.1B procurement and $67.0B O&S). Total life-cycle costs, excluding R&D, for an uninhabited FNA using the moderate case are $64.5B ($29.0B procurement and $35.5B O&S). Total life-cycle costs, excluding R&D, for an uninhabited FNA using the aggressive case are $49.4B ($24.7B procurement and $24.7B O&S). Numbers may not add due to rounding.
14. Assuming the cost increase from the F-35C to FNA is significant, equivalent to the same cost increase from the F/A-18E/F to the F-35C, total life-cycle costs, excluding R&D, for a human-inhabited FNA are $253.6B ($101.9B procurement and $151.7B O&S). Total life-cycle costs, excluding R&D, for an uninhabited FNA using the conservative case are $199.4B ($79.6B procurement and $119.7B O&S). Total life-cycle costs, excluding R&D, for an uninhabited FNA using the moderate case are $112.4B ($49.1B procurement and $63.4B O&S). Total life-cycle costs, excluding R&D, for an uninhabited FNA using the aggressive case are $85.9B ($41.8B procurement and $44.1B O&S). Numbers may not add due to rounding.
15. Some reduction in initial pilot training is clearly warranted. Air Force undergraduate training for remotely piloted aircraft has 60 percent fewer flying hours than undergraduate training for human-inhabited aircraft, even without accounting for follow-on T-1 / T-38 training. Scharre, "Can Automatic Reduce Training Costs."
16. Assumes a DDG-51 Flight III destroyer with an estimated cost of $1.6 billion (2015 Navy cost estimates). For more on DDG-51 cost estimates, see Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2015 Shipbuilding Plan*, Washington, DC, December 2014, 27.
17. The Congressional Budget Office estimates the total cost of the Ohio Replacement program, including R&D, to be between $102 billion and $107 billion. Ibid, 25.

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Center for a New American Security
1152 15th Street, NW
Suite 950
Washington, DC 20005

TEL 202.457.9400
FAX 202.457.9401
EMAIL info@cnas.org
CNAS.ORG

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1152 15th Street, NW
Suite 950
Washington, DC 20005

Tel 202.457.9400
Fax 202.457.9401
Email info@cnas.org

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