Continuously Pushing the Limits of Innovation, Technology & Conventional Thinking

H-1 Modeling & Simulation

November 2019

Background

- ASI presented previous RAM Engineering projects:
  - Reliability-Centered Maintenance (RCM) Analysis
  - Supportability Optimization Model (SOM)
  - Weibull (Life Data) analysis
  - Reliability Block Diagrams (RBDs) to predict spares procurements

- RAM projects involved numerous types of physical assets:
  - Aircraft (Fixed Wing, Helicopters, UAVs)
  - Ground Vehicles (BFV, FMTV, LVSR)
  - Facilities (Data centers, Hospitals)
  - Mining Equipment (Scalers, Elevators, Conveyors)
  - Other equipment (Engines, Tug Boats, S.E.)

Background

- ASI tasked with utilizing M&S tools and processes to:
  - Evaluate various maintenance concepts and compare results
  - Evaluate various scenarios and Courses of Action (COAs)
  - Incorporate aircraft schedules (Fleet introductions, Depot inductions, Retirements) at the BUNO level
  - Incorporate resource allocation and identify excesses and shortages
  - Simulate variations in Processes and Turnaround times (TATs) to minimize risk
  - Conduct Sensitivity Analyses by altering numerous factors
  - Identify the optimal allocation and scheduling/utilization of resources

- Models were developed to calculate and predict key metrics:
  - Downtime
  - Wait time
  - Availability
  - RBA
  - Resource utilization
  - Throughput
  - Costs
  - etc.

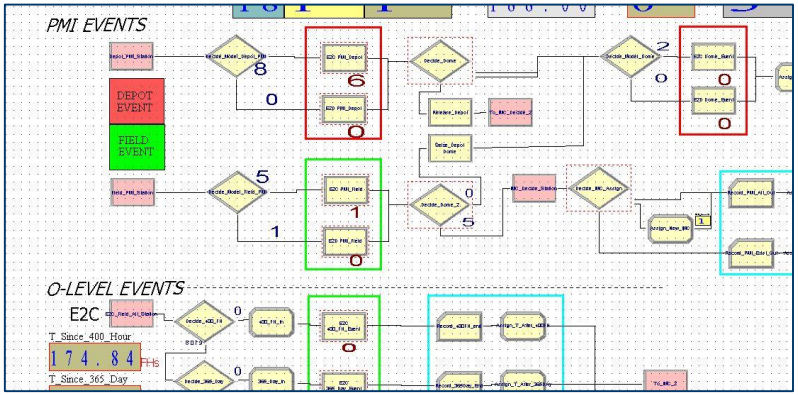
Modeling Application

Analysis Tool: Simulation with Arena

Utilizes discrete event simulation capabilities to evaluate current situation as well as alternative solutions

Sensitivity analyses also performed

- Example – Impact of 1 additional Electrician?
- Example – Impact of reducing TAT by 6 days?
- Example – Impact of additional hangar space?

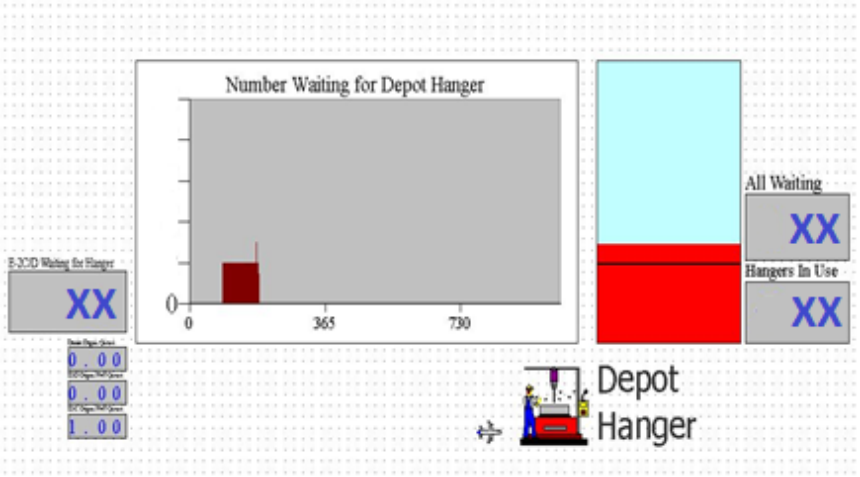


Optimization module identifies “best solution” based on inputs and objectives

Currently used in numerous industries, including DoD services

Inputs and Outputs

- Inputs include:
  - All current Aircraft with Delivery, Induction, Preservation, and Retirement schedules
  - Future Aircraft
  - Maintenance concepts (Intervals, schedules, locations, etc.)
  - Depot locations and resources (labor, special equipment, hangar space, etc.)
  - Process and TATs for Depot events, ISRs, modifications/changes/upgrades
  - Courses of Action (COA) scenarios
  - Alternative Maintenance concepts
  - Cost information
  - Supply chain/logistics information



- Outputs included:
  - Total Downtime and Wait time
  - Aircraft Throughput
  - Availability
  - Available aircraft (RBA)
  - Resource utilization metrics for various COAs
  - Cost metrics for various COAs
  - Optimal strategies based on desired Availability/Cost

H-1 IMP Modeling

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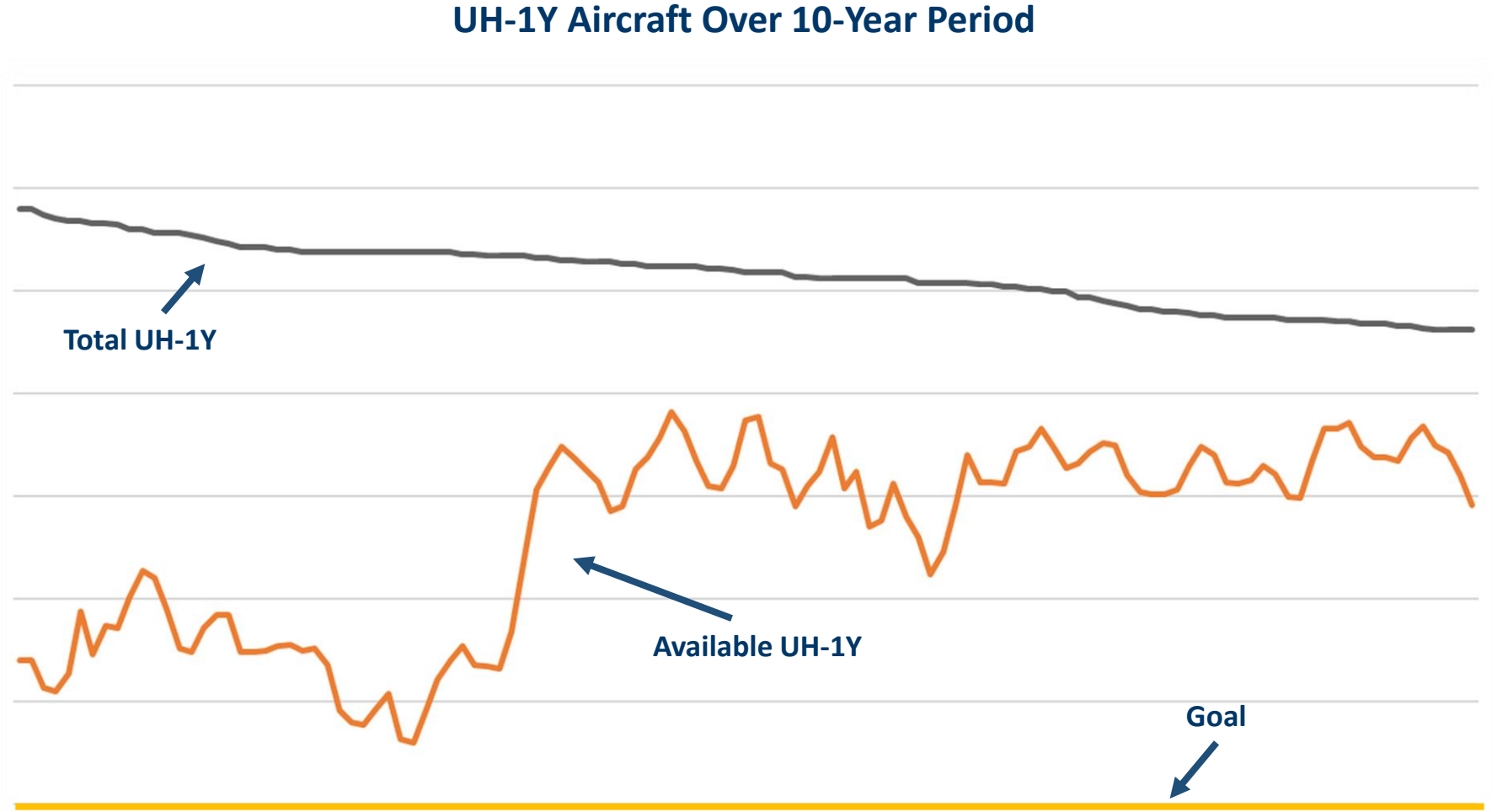
Objectives

- Model Depot inductions, ISRs, and Depot Modifications for UH-1Y and AH-1Z at each site
- Identify excess aircraft above RBA requirements to send for preservation
- Identify which sites will experience shortfalls/delays, and what additional resources would be required to meet Availability/Readiness requirements
- Incorporate predicted ISR occurrences
- Run sensitivity analyses on all inputs (ISRs, Depot mods, TATs, resources, etc.)
- Identify optimal allocation of resources
- Evaluate FH based IMC Concept
- Evaluate COAs provided by FST
- Run optimization routines on various factors

Status

- Model created with inputs/data from FST
- All BUNOs with locations and induction schedules
- Expected retirement dates calculated/incorporated
- ISRs and Depot modifications incorporated
- FRC Capacities at each site
- Current preservation schedule in effect

H-1 IMP Modeling – Results



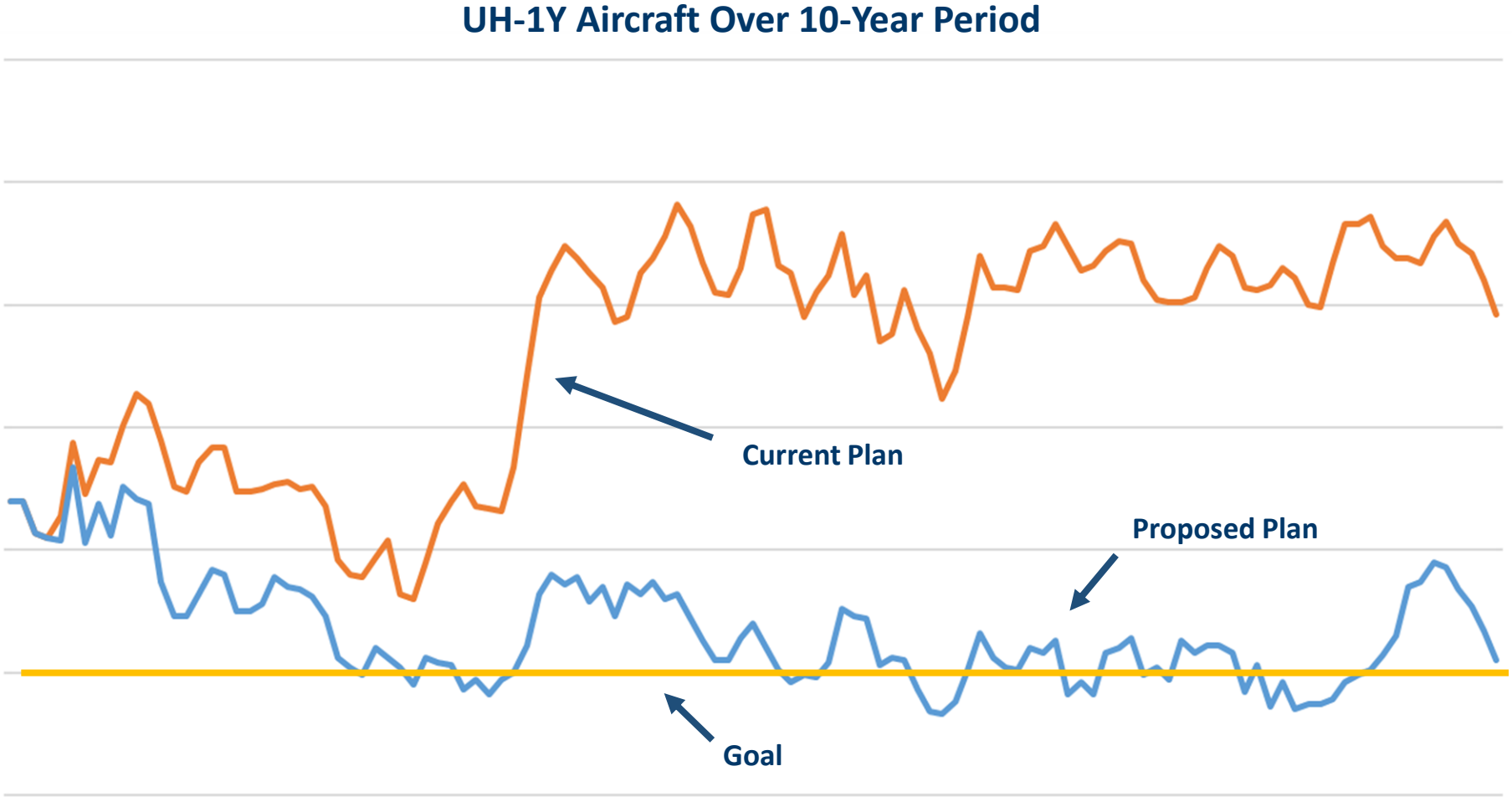
H-1 IMP Modeling – Results

- Average excess UH-1Y aircraft over PAA and depot requirements
  - Minimum of X aircraft and a maximum of X.
  - Number varied due to inductions, retirements, WIP, ISRs, MODs, etc.

- Depending on maintenance requirements, excess UH-1Y aircraft may be insufficient over 10 year period

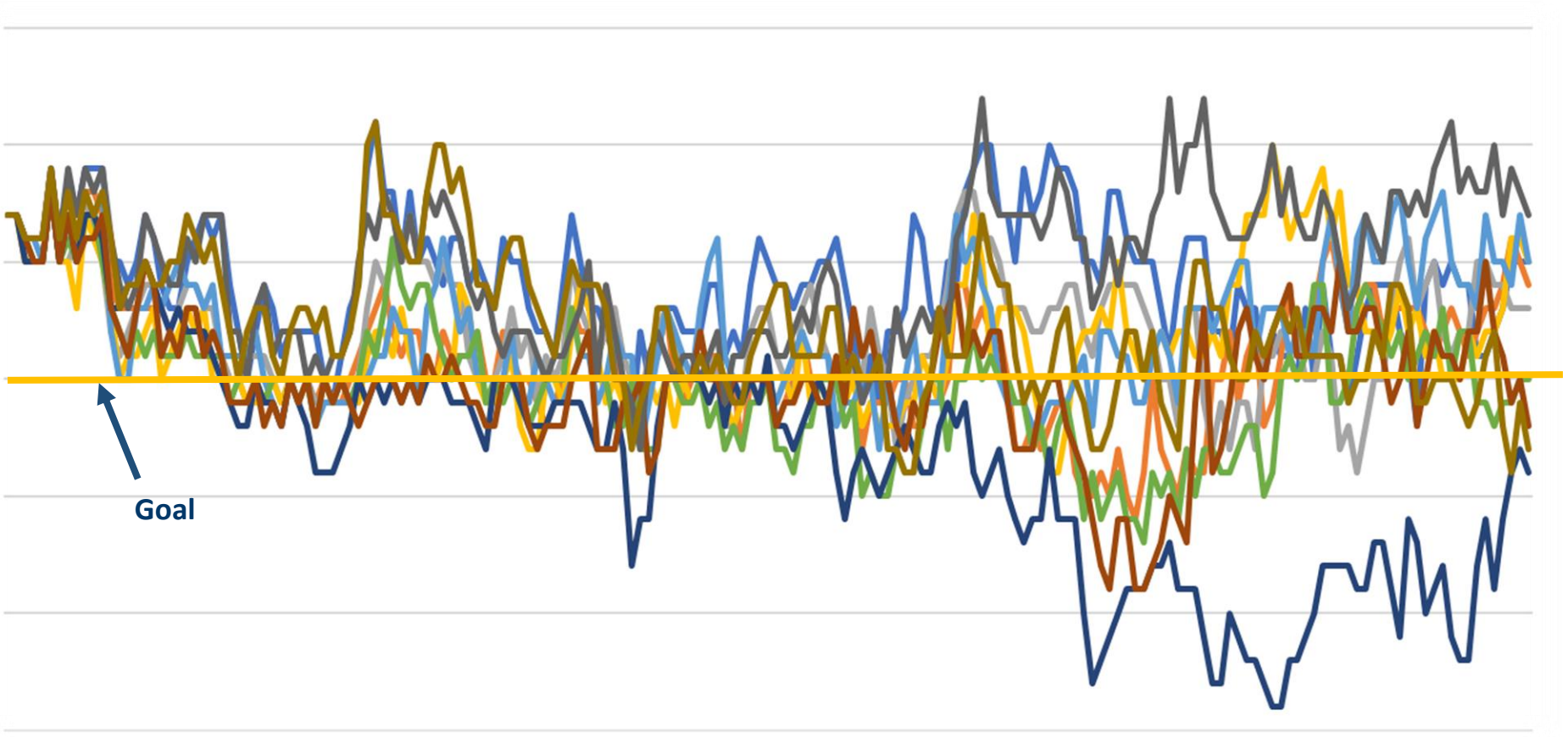
- Based on the results, an additional Long-Term Preservation policy of X BUNOs was simulated to reduce excess UH-1Y aircraft and approach the baseline inventory.

H-1 IMP Modeling – Results



H-1 IMP Modeling - Results

UH-1Y Aircraft Over 10-Year Period (10 Iterations)

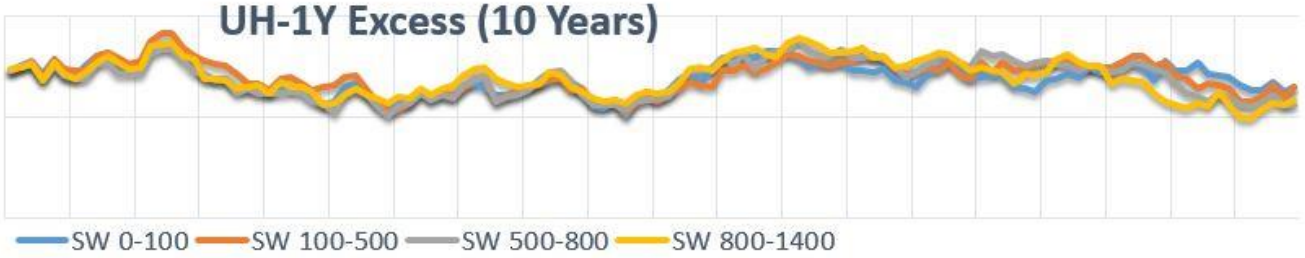


H-1 IMP Modeling – Results

- Considerations for long term preservation scenario
  - BUNOs selected for preservation (IMP history, location, flight hours, etc.)
  - Additional maintenance requirements due to long term preservation
  - Aircraft condition and configuration

- Selecting specific BUNOs for preservation allows regulation of IMP schedule
  - This offsets IMP to a desirable time frame
  - Allows control of which aircraft will compensate for BUNOs in AMARG

H-1 IMP Modeling - Results



H-1 IMP Modeling - Demonstration

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H-1 IMP Modeling – Status Update

- Continue to update and validate model against actual induction schedules
- Simulate various COAs for preservation
- Determine impact on fleet inventory
  - Vary number of aircraft selected for preservation
  - Vary preservation schedule
- Run optimization and sensitivity analyses on various factors to determine impact
  - IMP TAT, Depot Mods, increased ISRs, etc.

H-1 Manpower Study

- Model current state (As-Is) operations and predict and evaluate proposed changes of the H-1 maintenance manpower.
- Identify opportunities to improve process times and turnaround times associated with current squadron activities.
- Run sensitivity analyses and optimization routines to minimize risk associated with implementing proposed changes.
  - Utilize Arena OptQuest to Optimize mission capable aircraft while minimizing staffing.

H-1 Manpower Study – Model Details

- Model will run 10 repetitions with a simulation period of 10 years.
- Each squadron will be modeled separately to account for differences in shifts, manning, aircraft, and productivity.
- Three main work centers will be modeled.
  - Airframes
  - Avionics
  - Flightline
- All activities utilizing maintainers will be implemented.
  - Maintenance
  - Non-MAF duties
  - Non-Aeronautical duties
  - Administrative tasks

H-1 Manpower Study – Inputs/Outputs

- Inputs:
  - Shift schedules
  - Current resources and readiness correlation
  - Historical and current task turnaround times (FOD Walk, meetings, training, ATAF)
  - Historical aircraft downing rate
  - Historical maintenance manhour trends

- Outputs:
  - Mission capable aircraft
  - MMH per aircraft
  - MMH per Marine by MOS
  - Hours spent on non-MAF, non-aeronautical, and administrative tasks.

H-1 Manpower Study - Constraints

- Constraints are centered around staffing, working hours, and duties.
  - Staffing and working hours remain consistent throughout the simulation.
- The simulation will not extend a Marine's working hours before or after their assigned shift.
- Aircraft assigned to each squadron is fixed throughout the simulation.
  - Actual down aircraft are taken into consideration at the beginning of the simulation.
  - Based on manpower allocations, aircraft readiness may change.

H-1 Manpower Study - Results

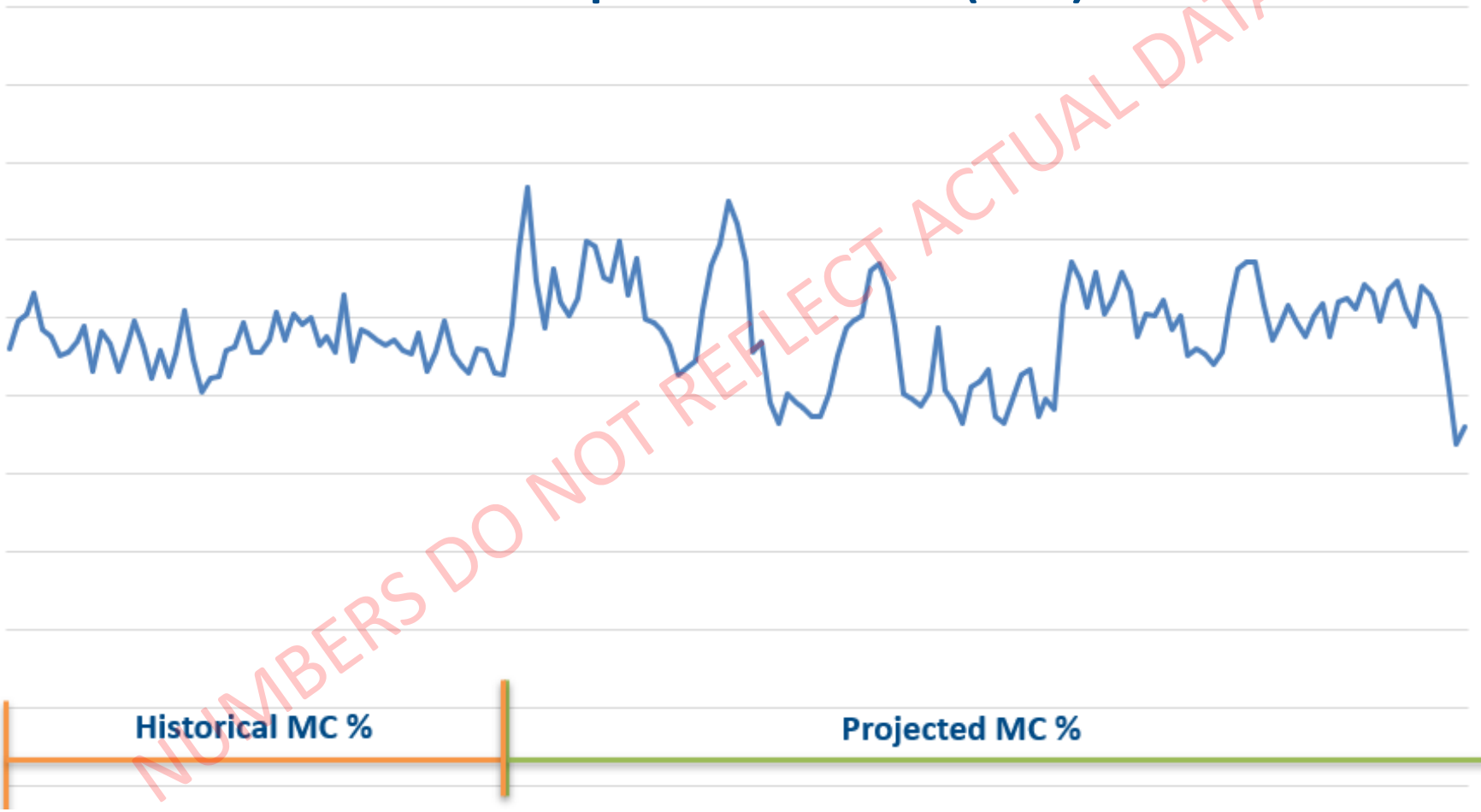
As-Is Manpower Breakdown per Day per Marine

	Airframes	Avionics	Flightline
Day Crew Workers Mustered	75	70	110
Night Crew Workers Mustered	70	65	90
MMH on Down Aircraft	1.50	1.20	1.00
Total MMH	3.30	3.00	2.50
Non-MAF Hours	1.40	1.50	2.70
Non-Aeronautical Hours	1.30	1.30	1.00
Administrative Hours	1.40	1.40	1.60
Unaccounted Time	3.60	3.80	3.20

- **Availability is considered 11 hours based on the shift length.**
  - **"Workers Mustered" is the average number of workers after Leave and FAPs are accounted for.**
  - ***Total hours include Qual utilization. "Per Marine" does not include Quals.**

H-1 Manpower Study - Results

Mission Capable Aircraft % (PAA)



H-1 Manpower Study - Results

- Average mission capable aircraft: 65.0%
- It takes an average of 50.0 DMMH to bring an aircraft from "down" to "up" status.
  - After disregarding the top and bottom 25% of values (removing outliers), the average equates to 13.0 DMMH.
  - Average of 300 DMMH on down aircraft over 30 days.
  - Average of 700 DMMH on down aircraft over 180 days.
- 30.0% of a Marine's time is spent on direct maintenance.
  - 40.0% of total DMMH are spent working on down aircraft.
- 45.0% of a Marine's time is spent on productive non-recorded activities.
  - 41.0% of that time is in support of D/T's, Fueling, Launch and Recovery, Towing, and Troubleshooting.
  - 36.0% encompasses FOD Walks, end of shift cleanup and Field Day.
  - 23.0% includes admin activities, tech training and meetings.

H-1 Manpower Study - Proposal

- Mission capability goal: 75%

- Two courses of action to increase MMH and decrease down aircraft turnaround time.
  - Increase maintenance productivity.
  - Increase staffing
    - FAPs/SAPs may also be reallocated among the work centers instead of overall increases.

- It is assumed that productive activities not recorded on a MAF are required in support of the fleet and will not be adjusted.
  - The amount of time during a shift that a Marine has available to complete maintenance will stay the same.

H-1 Manpower Study – FAP/SAPs

Muster/ASR Gap

CPL/LCPL	AF	AVI	FL	Total
CDI/CDQARs	80	100	100	280
FAPs	15	20	20	55
SAPs	140	70	100	310
Total	235	190	220	645

- Difference between available workers (510) and recorded On-Hand (1155) for CPL and below is 645 (CDI/CDQARs, SAPs and FAPs).
- Difference between average daily muster (480) and available workers (510) is attributed to Leave (30).
- Data collected between Jun ‘18 and Mar ’19.

H-1 Manpower Study – Proposal Results

Various Manpower Breakdowns per Day per Marine

	As-Is	Goal 1	Goal 2
Mission Capable % Average	65.0%	75%	80%
Workers Mustered	480	530	550
MMH on Down Aircraft	1.20	1.20	1.20
Total MMH	3.00	3.00	3.00
Non-MAF Hours	2.00	2.00	2.00
Non-Aeronautical Hours	1.20	1.20	1.20
Administrative Hours	1.60	1.60	1.60
Unaccounted Time	3.20	3.20	3.20

- **Availability is considered 11 hours based on the shift length.**
  - Non-MAF tasks include D/T, Fueling, Launch and Recovery, Towing, and Troubleshooting.
  - Non-Aeronautical tasks include FOD Walk, ATAF, and Field Day.
  - Administrative tasks include Tech Training, Greenside Training, and Meetings.
  - Unaccounted Time includes all breaks, lunch, and irregular events (i.e. medical, missing tool search, travel to/from work centers, etc.).
- **Goal 1: +10 AF, +30 AVI, +10 FL. Goal 2: +20 AF, +30 AVI, +20 FL.**
- **Without a change in current processes and policies, inefficiencies will increase with added Marines.**

H-1 Manpower Study

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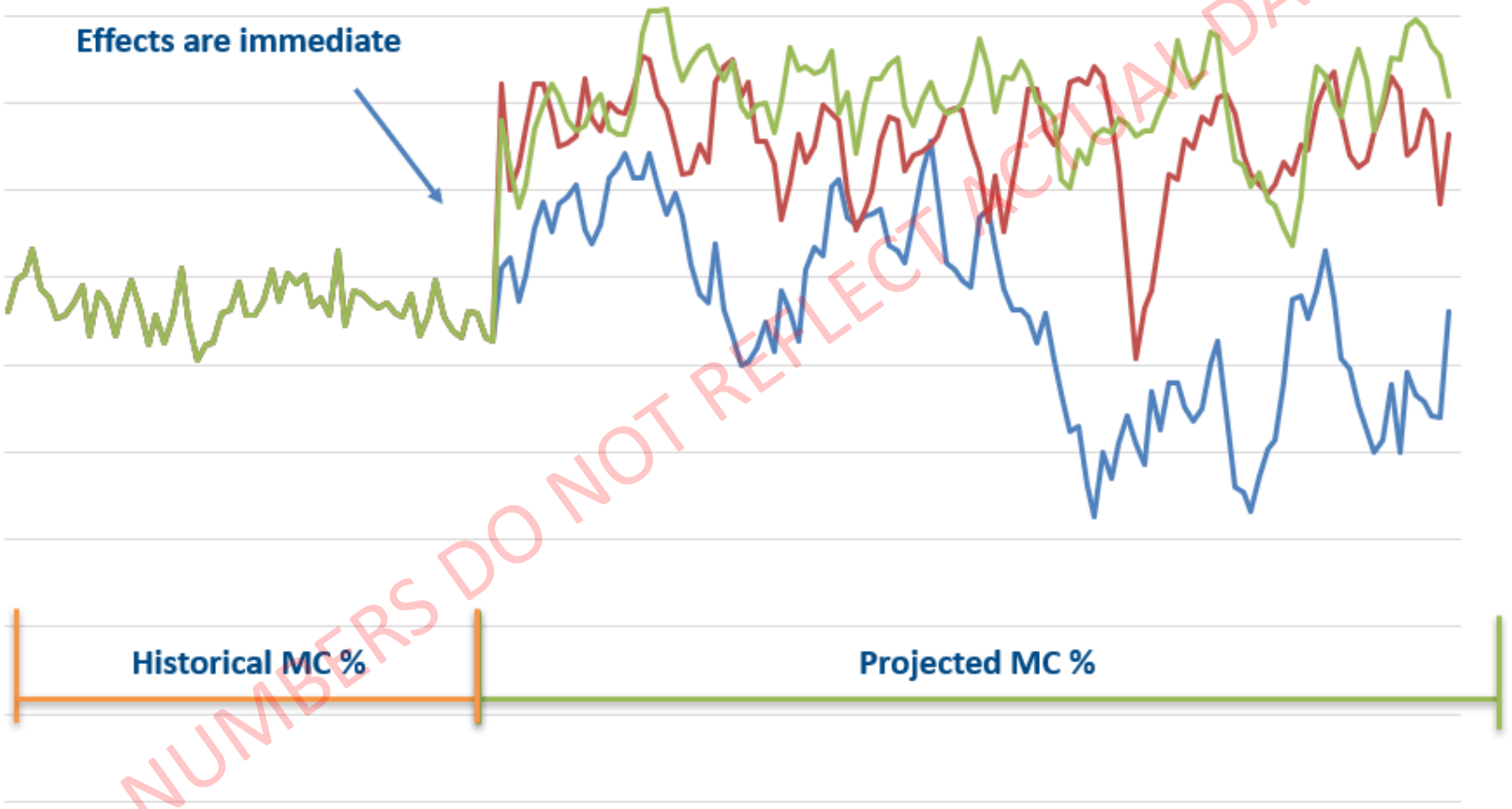
Mission Capable Aircraft %



Various Manpower Breakdowns per Day per Marine

	As-Is	More MMH	+20% Qual Utilization*	Combined
Mission Capable % Average	65.0%	75%	80%	85%
Workers Mustered	480	480	480 + 280 Quals*	480 + 280 Quals**
MMH on Down Aircraft	1.20	1.70	1.10	1.30
Total MMH	3.00	3.50	2.80	3.10
Non-MAF Hours	2.00	2.00	2.00	2.00
Non-Aeronautical Hours	1.20	1.00	1.20	1.10
Administrative Hours	1.60	1.30	1.60	1.50
Unaccounted Time	3.20	3.20	3.40	3.30

- **Availability is considered 11 hours based on the shift length.**
  - Non-MAF tasks include D/T, Fueling, Launch and Recovery, Towing, and Troubleshooting.
  - Non-Aeronautical tasks include FOD Walk, ATAF, and Field Day.
  - Administrative tasks include Tech Training, Greenside Training, and Meetings.
  - Unaccounted Time includes all breaks, lunch, and irregular events (i.e. medical, missing tool search, travel to/from work centers, etc.).
- ***All Quals (SSGT and below) were utilized for maintenance 20% of the allotted maintenance time.**
- ****Quals were not considered in the total Marine count when determining hours "per Marine."**

H-1 Manpower Study - OptQuest

- Arena OptQuest searches for the most optimal solutions within a model when given controls, constraints, and objectives.

- The quantity of workers for each shift and work center was optimized while maximizing mission capability and remaining within overall worker quantity.

- 100 simulations with 10 repetitions each were run for each scenario. Only one squadron was analyzed.

H-1 Manpower Study - OptQuest

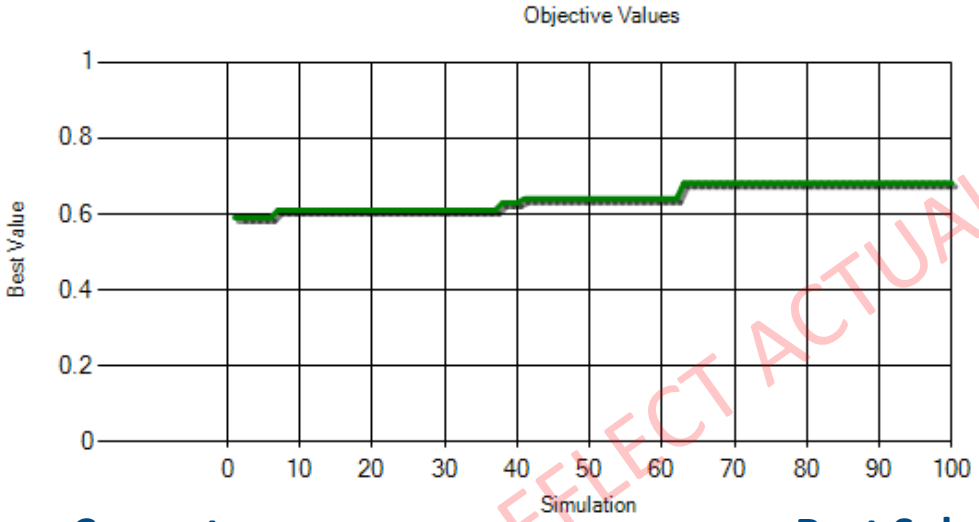
Best Solutions Based on Current Staffing on 1 Squadron*

Simulation	Objective	100_Number of Worker Day	100_Number of Worker Night	200_Number of Worker Day	200_Number of Worker Night	300_Number of PC Day	300_Number of PC Night	300_Number of Worker Day	300_Number of Worker Night
63	0.681369	11	7	8	4	4	3	11	5
72	0.663469	11	7	8	4	4	3	12	4
100	0.65781	13	7	8	4	4	3	10	4
71	0.657319	14	8	7	4	4	3	9	4
98	0.648641	11	6	15	4	6	3	4	4
92	0.647006	12	7	8	4	4	3	11	4
73	0.6466	14	8	8	4	4	3	7	5
41	0.639696	14	7	7	4	3	3	11	4
48	0.639043	13	7	7	4	3	3	11	4
89	0.6355	11	7	8	4	4	3	11	4
61	0.634907	13	8	7	4	3	3	10	4
80	0.631802	14	8	6	4	4	3	10	4
87	0.63171	13	7	7	4	3	3	10	4
38	0.629328	15	6	6	4	3	3	12	4
76	0.627513	12	7	8	4	4	3	10	5
65	0.625486	10	6	9	4	5	3	11	5
69	0.625071	15	9	7	4	4	3	7	4
44	0.623803	15	9	6	4	3	3	9	4
88	0.618113	11	7	8	4	4	3	10	6
55	0.616244	15	7	7	4	3	3	10	4
90	0.615458	11	6	8	4	4	6	10	4
93	0.614398	11	7	8	4	4	3	10	4
51	0.614362	11	9	9	5	6	3	4	6
67	0.613975	15	6	6	4	3	3	11	4
43	0.612953	10	8	10	4	3	6	8	4

Mission Capability

*Current total worker quantity: 53 E1-E3

H-1 Manpower Study - OptQuest



Current

	Airframes	Avionics	Flightline
Day	9	8	7, PC: 4
Night	8	7	6, PC: 4

Best Solution

	Airframes	Avionics	Flightline
Day	11	8	11, PC: 4
Night	7	4	5, PC: 3

- **Highest average Mission Capability: 68.1%**
  - **11.0% increase from current maintainer placement.**
  - **Though Avionics has more Total MMH per Marine, Airframes and Flightline have a historically higher ratio of Down Aircraft MMH to Total MMH.**

H-1 Manpower Study - OptQuest

Best Solution Based on T/O (78 E1-E3)

Mission capability increase: 3%

Current (76.6% MC)

Shift	Airframes	Avionics	Flightline
Day	15	12	8, PC: 5
Night	15	11	7, PC: 5

Best Solution (80.6% MC)

Shift	Airframes	Avionics	Flightline
Day	18	16	13, PC: 5
Night	8	5	5, PC: 8

Best Solution Based on ASR (72 E1-E3)

Mission capability increase: 5.1%

Current (73.5% MC)

Shift	Airframes	Avionics	Flightline
Day	14	11	7, PC: 5
Night	14	10	6, PC: 5

Best Solution (78.6% MC)

Shift	Airframes	Avionics	Flightline
Day	15	13	12, PC: 4
Night	7	7	4, PC: 8

Questions???