PERSPECTIVES ON GENERATING BUSINESS CASE ANALYSES FOR IMPLEMENTING HEALTH MANAGEMENT CAPABILITIES

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The Next 90 Minutes

- RoI versus Business Case
  - Are they the same?
- Why the need?
- What to consider in preparing a Business Case
  - It's complicated!
- Not teaching how to perform an RoI, because…
  - There's no cookie-cutter way to do it
  - There's no full blown examples of "how to"
    - If a company has an example/answer, they typically don't want to share it
- It's a discussive environment
  - The tutorial is a catalyst for discussion
    - Provided I get through 273 charts in 90 minutes

Business Case

The Take-Aways

- An *appreciation* of HM BCA complexities
- An *insight* on how to tackle a HM BCA
  - Using an aircraft as the example "system" because:
    - It's (arguably) the most complex example
    - It introduces most, if not all, of the salient features
- Cost Avoidance vs Cost savings
- The challenge for you!
  - Have I captured all the features?
    - Prizes for those who identify missing elements

Slide deck will be made available (email) to anyone who wants it

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The Presenter

- 40 years in and around military aerospace
  - 20 years as an engineer in the (Royal) Air Force
    - **From flight-line maintenance to fleet management to R&D**
  - 20 years as a mktg, bus dev, consultant to small businesses pursuing a complete range of programs with the Air Force
- Completed a 3+year assignment at the Air Force Research Laboratory (20 years ago)
  - Initiated the pursuit of PHM activities for gas turbine engines
    - Then JAST (and PHM) came along (became JSF, then F-35)
  - Member of SAE E-32 Technical Committee, then founder member of SAE IVHM Steering Committee and IVHM Technical Committee (HM-1)

ROYAL AIR FORCE

AIR FORCE RESEARCH LABORATORY

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And why do I care?

- As an Engineering Officer on a front line Squadron

  - Mission aborts on start–up
    - Especially multi-aircraft missions (2 ships, 4 ships etc)
  - Mission aborts during sortie
    - All the aircrew planning and preparation down the tubes
    - Sometimes involved aircraft from other wings/countries
  - My technicians fixed the airplanes
    - Not good when fault still persisted on next mission
      - Hurts their esteem and credibility in eyes of the aircrew

Why do I care (cont)?

- It’s a waste of money
- It’s inefficient
- Most of the events can be avoided
- For some (commercial passengers) it’s extremely frustrating
  - Weddings, funerals, crucial business mtgs……
  - “Time is money” to all of us

MFPT What's the Point of HM?

- I can think of only 3 reasons to pursue HM for any application or equipment.

- IMPROVE SAFETY
- **REDUCE COST**

- MINIMIZE INCONVENIENCE
- Are there any more….?

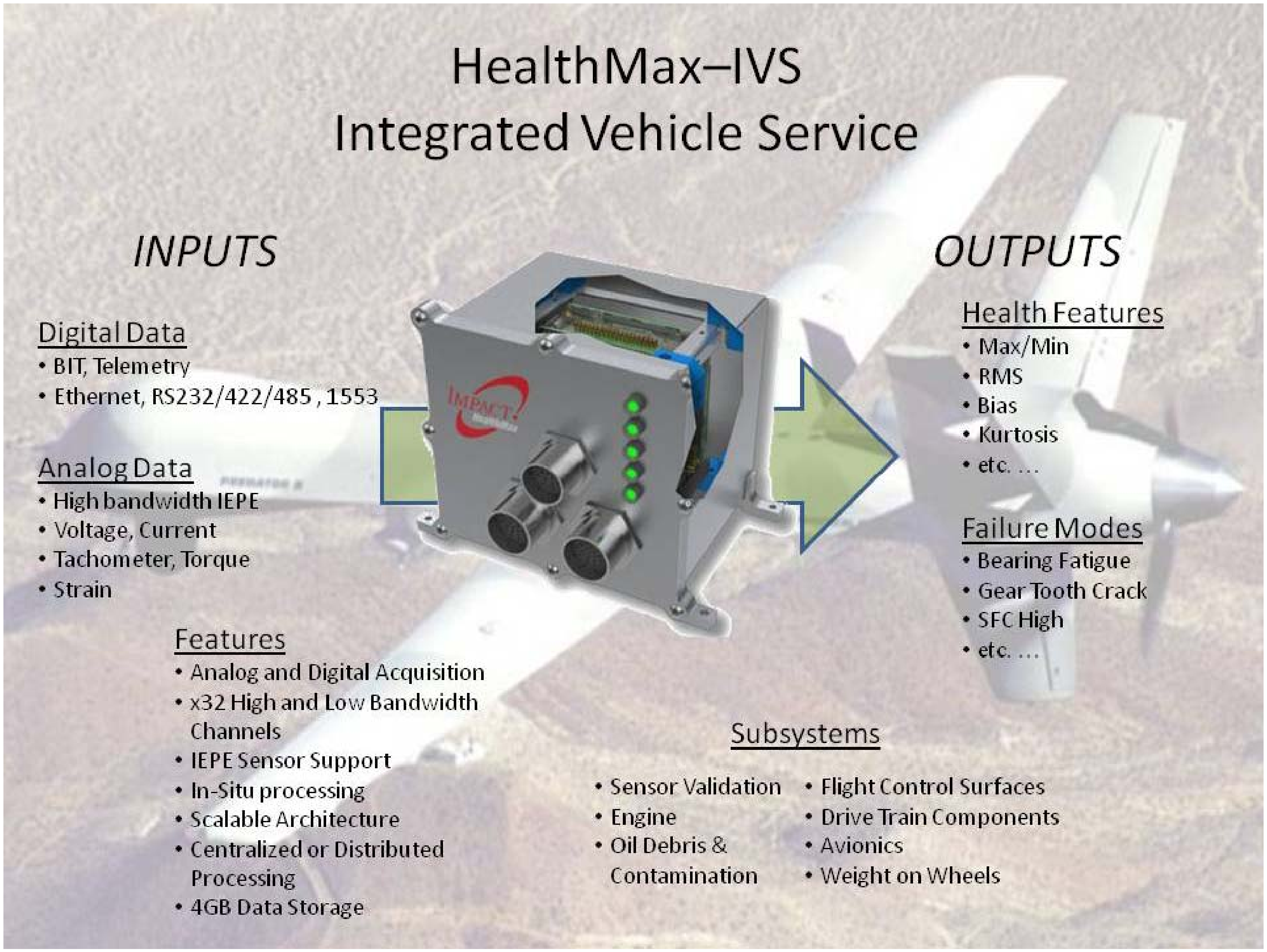
![MFPT logo]

Looking Back…….

- 1968…… 4 years before the oil embargo (and AIDS)
- AIDS (then) = Aircraft Integrated Diagnostics System
  - Measured 207 parameters on TWA, Air Canada, KLM a/c
    - Would make **aircraft** maintenance "on condition"
      - Maintenance predicted from recorder readings
  - Problems:
    - Needed better data recording and readout
    - Data analysis limitations; people became buried in data
    - Wiring for the installation was 620 lbs!
  - Needs: Data reduction and determination of which parameters were crucial so that a minimum number were recorded to still provide the required information

Bottom Line: The airlines initially loved it and TWA put it on their new 747s in 1969 measuring up to **512** parameters.

From 620lbs to 4lbs



And now……

- 45 years of technology progress:1969-2014
  - Especially in the last 20 years
    - Especially DoD
- The sense is that HM technology is no longer in doubt
  - Are the days of faulty sensors, indications, etc gone?
  - Is the HM technology really as good as it sounds?
  - Will it really save me $$$$?
- But, cast-iron business cases needed before precious investment funds can be won.
  - Seems that money to implement new things was more easily obtainable in 1969 (e.g. TWA 747).

MFPT RoI versus Business Case

- RoI = $\frac{\text{Return} - \text{Investment}}{\text{Investment}}$
  - Simple and objective!
  - Purely mathematical but.....
    - Accurately populating the 2 terms with all the requisite elements is (I believe) complicated
- Business Case Analysis (BCA)
  - Includes the RoI, but also opens the door for subjectivity
    - Argues the case based on numerical and non-numerical factors

Where to Begin?

- You have been given the enviable task to prepare a Business Case for implementing a PHM capability on a piece or fleet of equipment.
  - First considerations…….?
    - Are you an OEM, a service provider or a user (customer)?
    - Is the equipment a new design or legacy?
    - Is it military or commercial/industrial?
    - Who is the decision-maker?
      - What floats his/her boat?
      - What's the expectations (if any) re the "final answer"

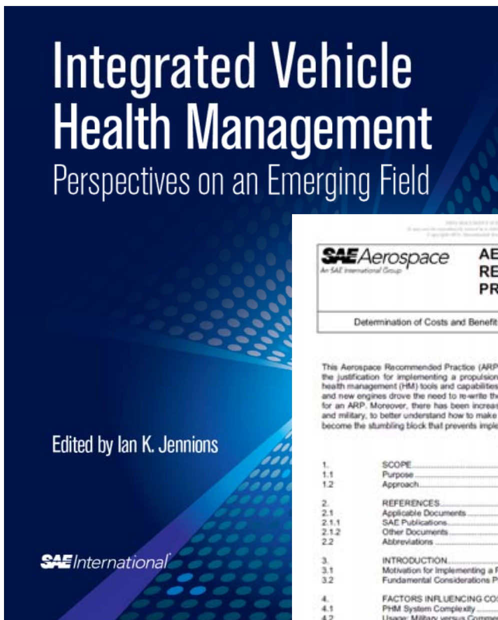
Strategy

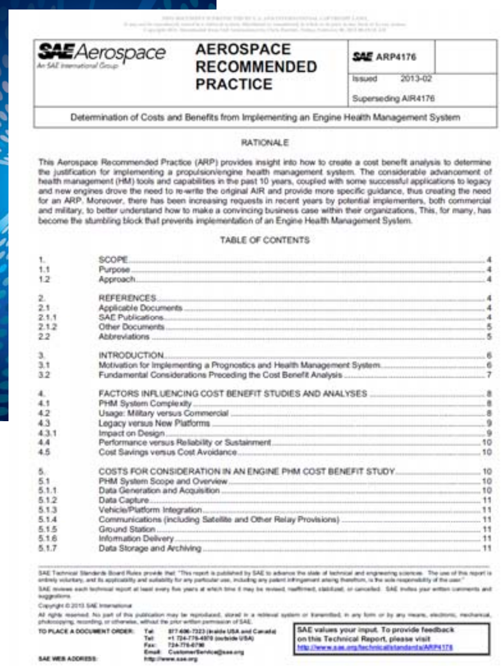
- What's the driving force/motivation?
- Is *existing* data available?
- Are there "comparables"?
  - E.g. Army CBM implementation on helos
    - Extrapolation might be acceptable
- Which parameters are acceptable?
  - E.g. cost savings vs cost avoidance
- Is there a "sweet-spot" for the final answer?
  - Too high and they don't believe you
  - Too little and it doesn't win the day

Recommended Approach, Based on…..

- SAE E-32, Aerospace Propulsion Systems Health Management
  - ARP4176
- SAE HM-1, Integrated Vehicle Health Management
  - ARP6275
- SAE Publications:
  - IVHM, Perspectives on an Emerging Field
  - IVHM, Business Case, Theory and Practice

MFPT Obtainable from:





SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP4176

Issued 2013-02

Superseding AIR4176

Determination of Costs and Benefits from Implementing an Engine Health Management System

RATIONALE

This Aerospace Recommended Practice (ARP) provides insight into how to create a cost benefit analysis to determine the justification for implementing a propulsion/engine health management system. The considerable advancement of health management (HM) tools and capabilities in the past 10 years, coupled with some successful applications to legacy and new engines drove the need to re-write the original AIR and provide more specific guidance, thus creating the need for an ARP. Moreover, there has been increasing requests in recent years by potential implementers, both commercial and military, to better understand how to make a convincing business case within their organizations. This, for many, has become the stumbling block that prevents implementation of an Engine Health Management System.

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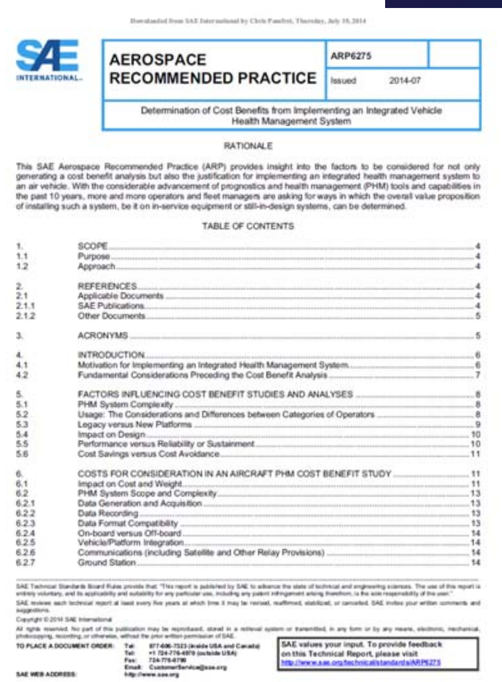

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AEROSPACE RECOMMENDED PRACTICE

ARP6275

Issued 2014-07

Determination of Cost Benefits from Implementing an Integrated Vehicle Health Management System

RATIONALE

This SAE Aerospace Recommended Practice (ARP) provides insight into the factors to be considered for not only generating a cost benefit analysis but also the justification for implementing an integrated health management system to an air vehicle. With the considerable advancement of prognostics and health management (PHM) tools and capabilities in the past 10 years, more and more operators and fleet managers are asking for ways in which the overall value proposition of installing such a system, be it on in-service equipment or still-in-design systems, can be determined.

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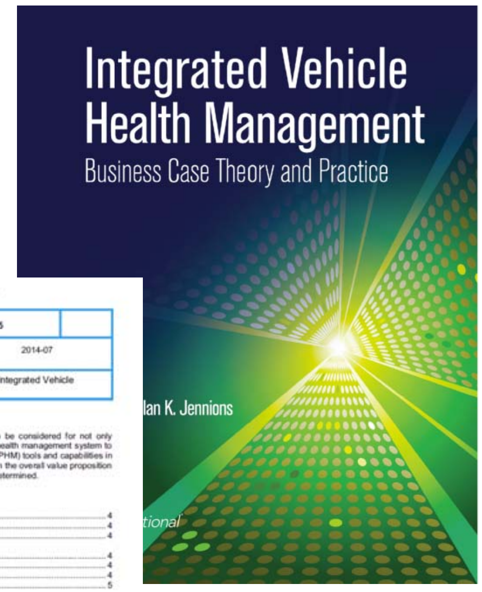

http://books.sae.org

Why is it so difficult?

- Quotes from an aerospace company
  - "One (difficult) issue is how to calculate the benefits of IVHM. That has always been a problem. We are a bit better but we can still do with more help. This is because IVHM avoids costs. *So how do you prove that (non-existent) costs would have been there had the IVHM not been in place*"
  - "We see real benefits in terms of cost savings because by using IVHM, we avoided a number of cancelations, delays etc. *But how you attribute those to IVHM is open to debate"*
  - "Businesses cases are very difficult and I think *it was more of an appreciation on a senior level that you almost have to do this to mitigate the risks*"

Why is it so difficult? (cont)

- Quote from an equipment company

“ Because you can say to someone ‘this (technology) can pick up the (possible) failures and then at the end of the year, when you sum up all the (possible) failures you identified, you will have a certain amount of savings’. But the problem is how to prove it would happen and save them that money, because it never happened. It is all a little bit gray and that is a problem”

Why is it so difficult? (cont)

- What's the baseline?
  - The cost of the "status quo" (humans, with inspection equipment, accessing the equipment etc…) is accepted without question.
    - Human fallibility is also "accepted"
  - Can we show that the "automated inspection" (health monitoring) is better/more efficient than the human fallibility element?
    - We (rightly) fuss about false +ves and –ves, but do we penalize the human for those errors?

There is a cultural/mindset battle to address that should not be underestimated

Why is it so difficult? (cont)

- Operators: Don’t want to fit an HM system unless it’s mandated. Why not? Do we *really* know?
  - Have they conducted an RoI or BCA?
    - If so, was the result not sufficiently convincing?
  - Maybe they don’t want to be bothered with a system *at the moment*. (Could be different in 10 years time)
- Equipment Manufacturers: Think it’s well worthwhile (“Real beneficial impact to the bottom-line, esp for commercial aviation”)
  - One helo OEM fits an HM system as “standard”

The Costs (Top Level)

- **Design,** including Requirements Definition
- **Development**, Build and V&V
- **Production**
  - Installation & Implementation
  - Data Collection, Handling, Transfer, Storage
- **Operational**
  - Training
  - Maintenance & Sustainment
    - Software, Hardware, upgrades
    - Configuration Management

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More (top level) Costs

- Unnecessary maint from False Alarms

  - (hopefully more than offset by the inverse)
- Fuel Costs
  - from weight of the on-board elements

- Time Value of Money
  - By not spending the money on an HM system, what would that money be worth in future years.

The (top level) Benefits (legacy)

- Reduced Maintenance Manhours
- Reduced Fuel Consumption
- Reduced Spares Turnover
- Increased Availability (or reduced fleet size)
- Fewer Mission Aborts
- Reduced Secondary Damage

The (top level) Benefits (new design)

- Weight reduction = less fuel burn or greater capacity for cargo/pax
  - Don’t charge pax for bags yet retain profit margin!
- Reduced parts count (less redundancy)
- Increased life of (lifed) parts
- Reduced fuel consumption (from less fuel dumping, turn backs, ground runs…..)
- Increased availability

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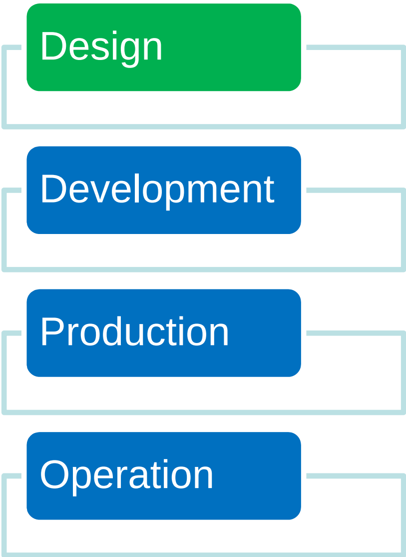
PART 2

A DETAILED LOOK AT THE INGREDIENTS OF EACH COST AND BENEFIT PARAMETER

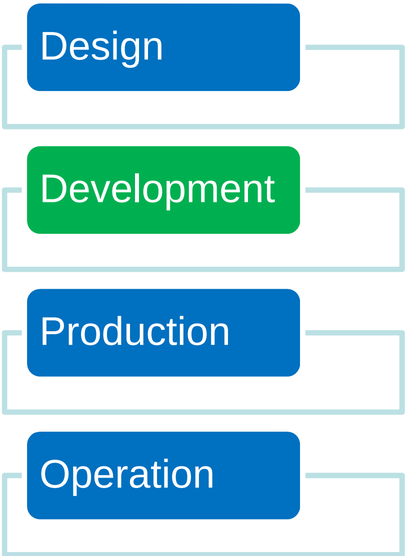
COSTS: Design, including Requirements Definition

- What Failure Modes are to be detected? (FMECA, done?)
- Do the sensors exist?
  - If not, cost of introduction/implementation
- How will the HM system be integrated with the platform?
  - Does this generate additional related costs (mods)
- Where will the data be collected?
  - On-board or downloaded (and how often)
  - Will satellite comms be required?
  - Is a secure system needed?
- Where/how will the data be stored/archived/accessed?
- Software creation for data analysis
- System adaptability for future growth/platform changes



COSTS: Development, Build and Qualification (V&V)

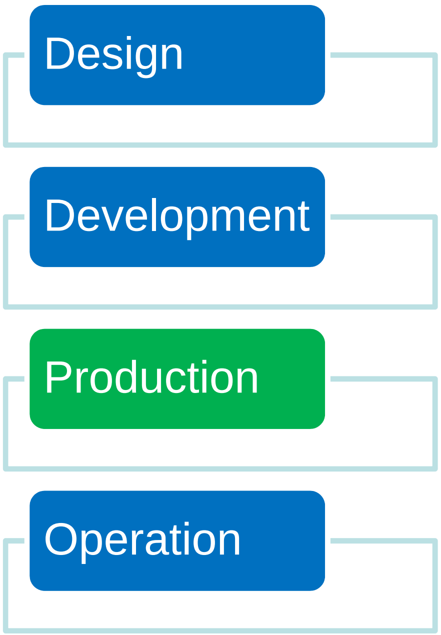
- Even if a HM system is COTS available, the following elements need to be considered & costed from a materiel and labor (and asset) perspective:
  - SWaP impacts on the host platform
    - Are there additional associated costs?
  - How many iterations to create the prototype HM system?
  - How much V&V is needed?
    - To ascertain that false +ve and –ve rates are being met.
    - Downtime of an operational asset as the surrogate host
  - How much durability/reliability needs to be demonstrated?
    - To meet requirements definition
    - To assess growth and adaptability



Finally, does the designed system capture the totality of issues to avoid an "Achilles Heel"?

COSTS: Production & Implementation

- Hardware costs (i.e. cost of the HM system package)
- Installation on the platform
  - Labor
  - Asset downtime (loss of revenue)
- Functional testing and sign-off



COSTS: Operational and Sustainment

- Labor for Data Handling, Transmission, Storage and Analysis
- Equip Costs for Data Storage & Transmission
- System and Software Upgrades
  - Better “technology”
  - Retain compatibility with Platform Tech Data
  - Adapting to platform needs (new failures etc)
- Training and re-training
- Adverse Impacts on Host Platform
  - Additional fuel costs from hosting HM system
  - Unnecessary Maintenance from HM system imperfections
    - False positives (and negatives)

BENEFITS

…..considered to be the more complex aspect of the BCA, because so many of the parameters are interconnected and cross-feeding

BENEFITS: Reduced Maintenance Manhours

- *Current* maintenance manhrs/operating hr?
- Anticipated or known figure with HM system from:
  - Less Scheduled Inspections
  - Less Unscheduled (surprise) Maintenance
    - What was once unscheduled now becomes "scheduled"
  - More efficient maintenance (> "right first time")
  - Less secondary damage
- Are maintenance credits available?

BENEFITS: Reduced Fuel Consumption

- Fewer ground runs for system checks, from:
  - Fewer “speculative” component changes
  - Lower frequency of parts removal/replace because of
    - Longer life of installed parts
    - Better diagnoses of on-platform faults

- Fewer mission aborts/turn-backs
  - Less fuel dumping to reach premature landing wt
  - Less fuel burnt from incomplete missions
  - And the impact on other orgs (air to air refuelers, other combat a/c)
- Reduced platform weight from reduced redundancy.
- More efficient engines and flight control surfaces (inefficiencies and degradation is seen earlier)

BENEFITS: Reduced Spares Turnover

- Less speculative removal of parts
  - Remove & replace fewer parts believed to be at fault
  - Removing fewer parts so as to reach the “faulty” part and potential for invoking secondary damage
- Less testing at Back-shops/Depot
  - Reduced labor, equipment, infrastructure costs
  - Increased spares availability, reducing AoGs

BENEFITS: Increased Availability (Ao)

- What is a 1% increase in Ao worth?
  - If it is calcuable, is it linear?
  - Same for mil and commercial?

- In theory, x% increase in Ao = :
  - x% less in asset fleet size or
  - x% increase in operational capability or
  - up to x% "dividend" in operational efficiency
    - e.g. spare assets more likely to be available to meet unexpected needs.

How will the decision maker view this benefit?

Is it truly application specific?

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BENEFITS: Reduced diversions

- What are the costs associated with a diversion?
  - Additional Landing Fees
  - Passengers put up in hotels, and fed for x hours/days
  - Replacement parts shipped to location
  - Maintenance crew dispatch & recovery costs
  - Loss of revenue generating asset
  - Negative publicity (it makes the news)
  - Loss of customer loyalty or increase in dissatisfaction

What's the difference between the black & red elements?

Does it matter? How do you know?

BENEFITS: Reduced Secondary Damage

- Is this even sufficiently significant to consider?
  - Human induced
  - Physical disturbance
  - Requires historical data to
    - Ascertain the size of the problem and
    - Quantify the likely reduction
  - If data is not available, then a (gu)estimate will be needed.
  - Every instance of secondary damage will have an individual cost
    - And what ancillary factors (e.g. delayed effects) are hidden?

Do we know if this factor is the tip of an iceberg?

BENEFITS: WEIGHT REDUCTION (New Platforms)

- Designing a HM system into the platform brings additional benefits
  - E.g. Paper (David Boden, Lockheed-Martin) to show removal of dual flight control actuators w/a HM system fitted.
  - JAST…. JSF…. F-35; single engine decision based on PHM
- What does a 1lb reduction in platform weight provide in benefits?
  - Circa 2000, 1lb = $1M over platform life cycle (commercial)
    - Less fuel upload (decreasing exponential relationship)
    - Is it linear?
    - Is the saving really materialized?
    - Will the decision-maker buy the argument?

- Reduced parts count leads to ripple of other benefits

BENEFITS; REDUCED PARTS COUNT (New Platforms)

- Fewer parts because of reduced dependency on duplicated systems

  - Reduced weight
    - Reduced fuel carriage or increased payload
  - Reduced operating costs
    - Reduced spares pool

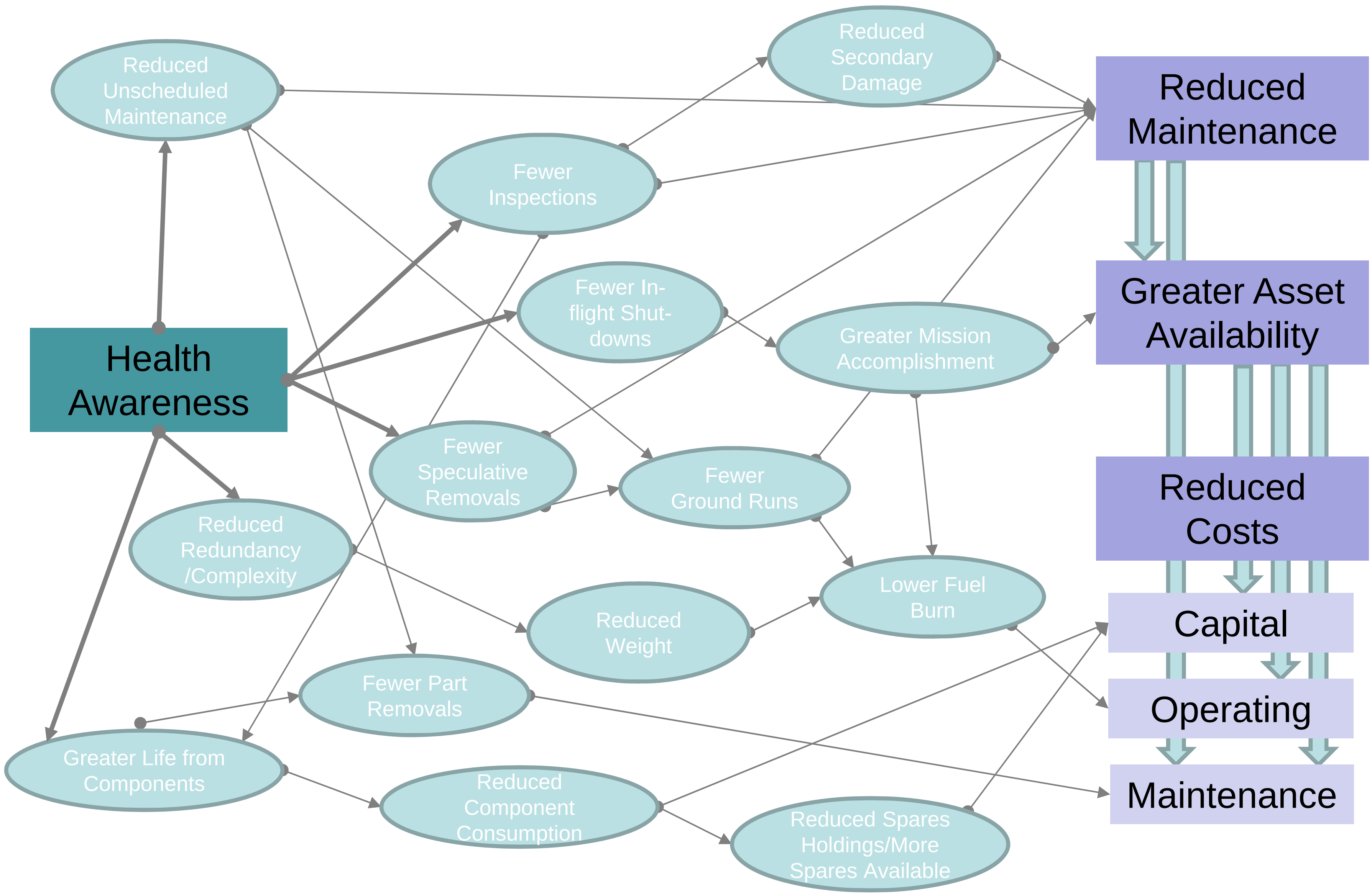
BENEFITS: INCREASED PARTS LIFE

- What parts are "eligible"?
- How much life could be realized?
- Does it lead to:
  - A reduced pool of spares
  - Less (scheduled inspections) maintenance
  - Reduced secondary damage
  - Reduced inspection equipment
  - Increased asset availability

BENEFITS: The *Qualitative* Elements

- IF a HM system leads to a greater %age of on time arrivals and departures (reliability), how does this influence the customer (in revenue terms)?
  - If airline "X" was a front leader for these factors, would the customer reward that airline with their business?
    - Do you put a value on it? How?
      - And the reverse?; e.g. –ve publicity (Carnival cruise line)
    - Can an operator afford not to embrace IVHM?
    - Is this part of the decision-maker's thinking?
      - Compare to frequent flier miles
- Military: Will be flying airplanes that are 80+ years old.
  - Unchartered territory (and a great technical opp/challenge)
  - Increasing age leads to new, and an increasing number of faults
    - Corrosion, cracks, wiring, ……….
  - Can we afford not to address sustainment issues with a (P)HM system.

The Spaghetti of it all



Final Thoughts… to the Future

- Maybe the OEM should take the lead and provide a HM system as “standard”
  - OEM’s seem to be convinced of its value
  - The OEM will benefit from seeing operational data on its systems and subsystems
    - Leads to better understanding of design faults and generates faster remedial action
  - The Operator will see benefits and “grow accustomed” to it without financial outlay
- If an operator is considering implementation (on legacy fleets), look to the US Army for a retrospective CBA.

Summary

- IVHM technology is different from other technology implementation
  - It doesn't provide something tangible but promises to prevent something from happening that has been tolerated in the past.
  - So, a motivating need is required (save money, improve safety…)
- Developing a business case for IVHM is a tough challenge
  - Marketing and persuasion is needed as well as the $$$ calculations.
    - OEM's seem to have become convinced but initiated by/from the top execs.
- The (arguably) most important element is determining the strategy for each unique case/situation.
- Data/knowledge about the existing construct can help establish a baseline or show the change in metrics after implementation.
- Ultimately, "Beauty is in the Eye of the Beholder"
  - Something that engineers aren't used to