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**Weight Control Responsibility, Authority, & Accountability**

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787 Weight Engineering
The Boeing Company

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# WEIGHT CONTROL
# RESPONSIBILITY, AUTHORITY, AND ACCOUNTABILITY

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## Abstract

The roles and responsibilities of the Weight Control Engineer are clearly defined within the Weight Engineering Organization at the Boeing Company. Unfortunately, personnel in other disciplines within the Boeing Company often misunderstand our role - for a variety of reasons. Couple that reality with the trend toward outsourcing design and build responsibilities – whereby partnering companies furnish personnel from various disciplines. Supplying Weight Control Engineers can sometimes present a dilemma if that function does not exist within that company or if the company simply uses the weight engineer as a data recorder. Typically, partnering companies request individuals to perform this role with limited or no understanding. The burden of responsibility now belongs to Boeing to provide the necessary training. Additionally, the new employee has minimal exposure to the weight engineering function. These conditions mandate a philosophy of continual training to address the needs of many incoming personnel to Weight Engineering. This paper focuses on highlighting weight control attributes, addressing responsibilities, command of subject / authoritative effectiveness, and resultant accountability. These principles are intended to establish the solid foundation. Coupled with other SAWE papers pertaining to Weight Control, they will both aid and expedite the individual toward becoming effective in performing weight control.

## Introduction

The demand for weight control expertise continues to be at the forefront of critical skills in the aircraft industry. Press reports from three recent programs highlight weight criticality.

> ***US Air Force Press Releases* by *Scott Elliott***
>
> *3/24/2004 - WASHINGTON -- Early reports show that the Air Forces next generation close-air support aircraft has a weight problem.*
>
> ***Joint Strike Fighter sheds pounds.(Digest)***
> *Armada International, October, 2004*
>
> *"The F-35 Joint Strike Fighter (JSF) team claims it has succeeded in peeling 1225 kilograms of 'unwanted' weight from the Short Take-off/Vertical Landing (Stovl) version of the aircraft, and in the process has increased propulsion efficiency and reduced drag. This remarkable feat, which ..."*
>
> ***Airbus A380 five tons overweight at inauguration***
> ***(Agencies)***
> ***Updated: 2005-01-18 16:11***
>
> *The Airbus A380 superjumbo is five tonnes overweight but this is less than one percent of its maximum weight and airlines are not worried, John Leahy, commercial director at Airbus, said on Tuesday.*
>
> *Tuesday, November 7, 2006*
>
> ***787's big sections may be in Everett by February***
> ***But Boeing redesigning parts to lower weight of Dreamliner by 2.5 tons***
>
> *By JAMES WALLACE*
> *P-I AEROSPACE REPORTER*
>
> *The first large sections of The Boeing Co.'s 787 Dreamliner could arrive in Everett by February, as the pace of the company's most important program quickens before first flight in late August.*
>
> *But significant challenges remain before the first plane is delivered to All Nippon Airways of Japan in May 2008, Mike Bair, vice president and general manager of the program, said Monday.*
>
> *Not the least of those is weight.*

Unfortunately, weight control fundamentals are not part of the engineering classroom curriculum on the college campus – at least not yet. Instilling weight control principles upon a diverse engineering workforce in a global environment presents a challenging endeavor. Often, the new weight control engineer knows little about the Boeing weight control function. In addition, the experienced engineer, outside the weight engineering organization, has little understanding of the roles and responsibilities of the weight control engineer and typically perceives that as more of a weight "recording" function. Therefore, the weight engineering leadership team must be diligent toward continually educating and molding individuals to perform effective weight control.

[1] Aeronautics is now a collaborative global reality. Society influences and necessitates improvements in future aircraft design and manufacturing. Environmental awareness coupled

with rising fuel costs are causing airlines to seek improved performance through reduced emissions and maintenance, lower fuel burn, abated noise levels, and yes - less weight. Since weight represents a key driver, any reduction will yield improvements in emissions, fuel burn, and noise. Leveraging political and business interests through design and manufacturing partnerships will facilitate performance improvements through collaboration with top tier suppliers around the world. Within this business model, the weight control engineer must be a vital contributor and “responsible” for ensuring development of environmentally sensitive, high performing products within a global marketplace.

The Boeing Weight Engineering leadership expects the weight control engineer to impart “authoritative” weight control proficiency in the midst of a quickly changing business environment. Weight Engineering’s functional role in airplane development takes on even greater importance in an environment mandating extremely aggressive weight targets. We are “accountable” with finding ways to be more efficient in accomplishing our statement of work, providing more accurate weight analysis, and supplying ever increasing levels of information, visibility, and communication. Our success depends on continually increasing our ability to work together with our partners, suppliers, and the design community - leveraging the best technology available to design, build, and assemble weight efficient parts that satisfy program requirements and objectives.

The Weight Control Engineer’s effectiveness toward responsibilities, command of subject or authority, and resultant accountability will ultimately determine the aircraft weight level of new or existing aircraft. Level of effectiveness is determined by acquisition and utilization of the following four attributes:

1) Big Picture / Vision / Strategy
2) Teamwork
3) Technical Competence
4) Personal Attitude / Challenge / Development

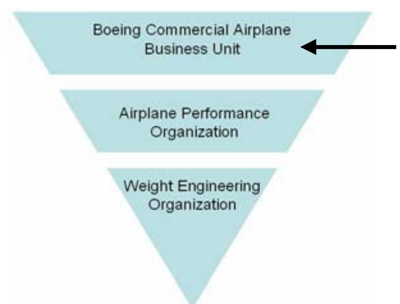
Typically, the new engineer, inducted into the weight control assignment, possesses concerns about their responsibilities to Weight Engineering as well as to the company. The information contained herein is targeted at providing a foundation for the Weight Engineer - understanding their role and how to mature into an effective contributor at developing lightweight engineering solutions. A detailed explanation of these primary attributes follows.

1) **Big Picture / Vision / Strategy**

Our mission statement is to ensure the weight efficiency, weight compliance, and loading flexibility of our company's products. Acquiring the Big Picture, Vision, and Strategy attribute will enable the formation of a customized weight management plan. The weight management plan must align with program management objectives. They must endorse it through words and actions. This should translate into compatible words and actions by the design community, ensuring commitment and achievement of airplane performance goals within parameters such as program schedule and cost. The weight control engineer will be primarily responsible for implementation of this plan through rigorous task priority setting coupled with focused design activity.

The weight control engineer must communicate frequently to the design team "where we are, where we are going, why we want to go there, and how we are going to do it". The weight control engineer serves as a conduit to make sure this information is transmitted and implemented.

How does one gain the "Big Picture" perspective? The weight control engineer can start by acquiring and learning about the company vision (i.e. commercial airplanes business unit). This knowledge is transferred from the weight control engineer to the design community throughout the airplane development via team and individual meetings, trade studies and basic work statement analysis. While this paper focuses on the relationship between Weight Engineering and the Boeing Commercial Airplane Business Unit, the attributes may be applied to any company level business unit and the Weight Engineering organization.




How do Weight Engineering, Airplane Performance, and the Commercial Airplane Business Unit interface? It begins with the weight control engineer developing an understanding of the commercial airplane business unit's goals. The commercial airplane business model and vision provides information about new or derivative products, how they fit within the family, and comparable development timeframe. For instance, the commercial business model will describe what new technologies and customer amenities are required for a new airliner to be successful in the market place.

Boeing 787-8 Roll-out

Existing Boeing 7-Series Family

How will Weight Engineering contribute to that family plan vision? Considerations to assist in formulating an internal plan include:

- What will be the commercial airplane near-term revenue percentage contribution to the company?

  *This will provide insight into expectations for new commercial products or improving existing fleet. If performance is required to improve the fleet, then a proactive weight effort may be necessary.*

737 Next Generation Family

787-8 Dreamiliner

747-8 Intercontinental

  *However, if reducing cost or production flow time are the focus, the weight control engineer should provide guidance when weight is impacted.*

- What is the customer composition (Domestic or Foreign, Low-cost Carrier or extended range, etc.)?

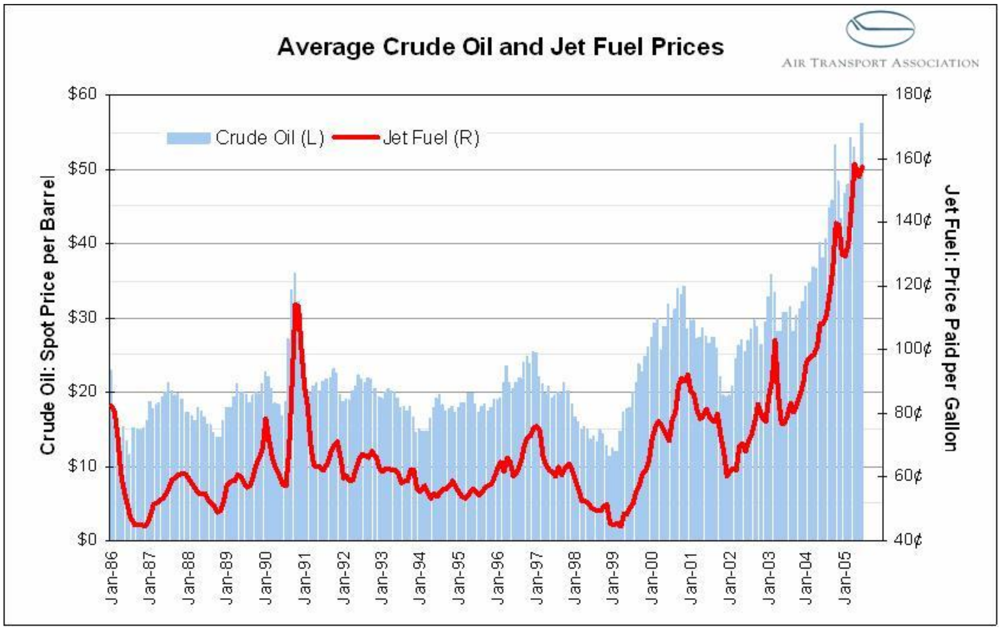
  *This information will provide insight into what technologies may be required due to market demands. This will also influence manufacturing rate.*

- What are the current commercial airplane programs (787, A380, A350XWB, etc.) in progress?
  - What are the current and expected sales?
  - What are the schedule, cost and performance requirements?

  *If entry into service is in 5 years, what are the available technologies that fit within a 5-year period? The weight reduction plan must be realistic and based on achievable technology within the program constraints.*

- What is the expected business unit revenue growth per year (3%, 6%, 10%, etc.)?

  *If the commercial business is to grow, perhaps "new" aircraft designs will be required, dictating a fuel-efficient airplane to compete with high fuel prices or a competitive market.*




- Does the market demand for a new airplane justify the development cost? Alternatively, does a derivative airplane, with upgrades, make more "business" sense?

  - What are the new technologies and customer requirements needed to attract the flying public? What new features give the airlines a competitive advantage by favoring one company over another?



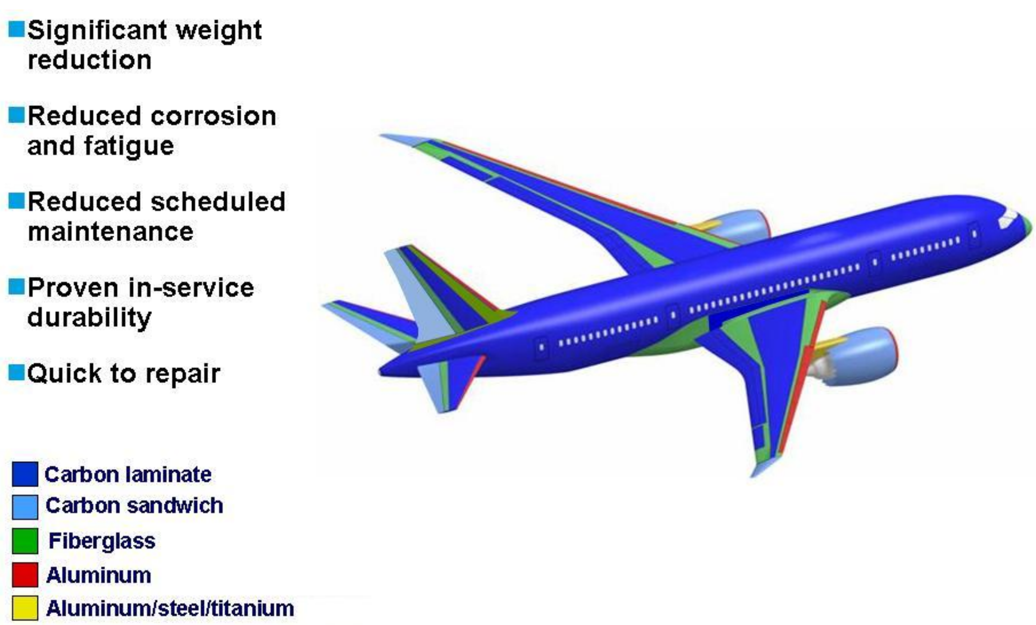



- What is the R&D plan to support new technology implementation on new aircraft design?

    *New material systems and advanced architectures/designs require funding and staffing to be ready for implementation.*


*787-8 Fuselage "One Piece" Barrel Test Article*

*Schedule often prevents new technologies to be "fully" implemented on a new airplane program. The technology implementation plan and test schedule must be detailed (component level) and communicated frequently. A robust review process must accompany the technology implementation plan. If projects are off plan, weight implications must be considered.*

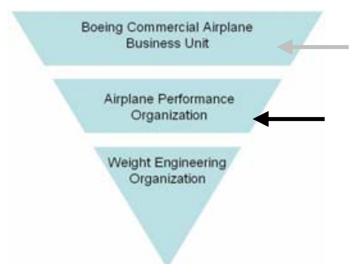


- What is the Competition's market focus?
    - Understand the competition's market focus (regional, single aisle, middle of the market, jumbo, etc.). How does that compare to our market focus?
    - What new performance improvements or technologies are targeted for our competitor's product?

        " The all-new composite wing design lifts the A350 XWB cruise speed to Mach 0.85 (the cruise speed of the A380). Excellent aerodynamics, together with advanced high lift devices and advanced systems contribute to greater fuel economy in all flight regimes and on the ground. Moreover, the new Rolls Royce Trent XWB engine, producing up to 92,000lb of thrust, will draw on the latest manufacturing, materials and thermodynamic expertise to deliver lower fuel burn and lower maintenance costs while minimising the noise 'footprint' around airports and reducing environmental impact. "
        -Airbus Website March 2008

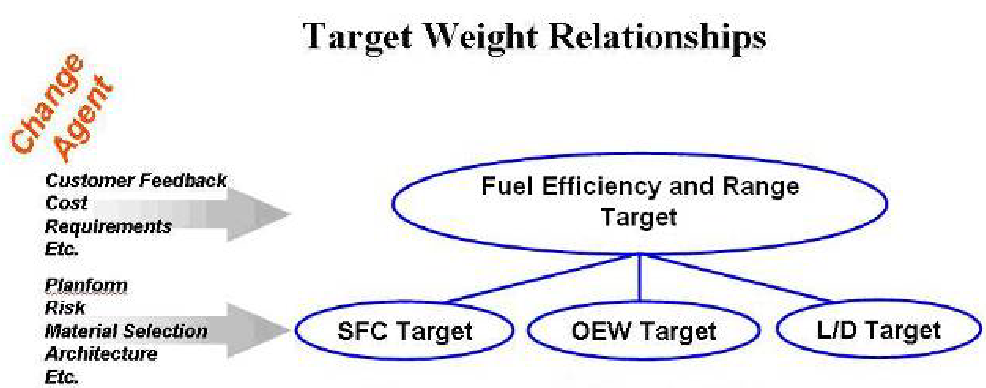
    - Does the competition have an unchallenged market? If so, are there enough sales forecasted to warrant a new airplane or derivative?

Second, assuming a new commercial airplane or derivative airplane is included in the commercial airplane unit's business plan, the weight control engineer must learn how the aircraft weight level is affected by aerodynamic and propulsion issues.




- What is the performance requirement balance between engine performance (SFC or specific fuel consumption), aircraft operational empty weight (OEW) and aerodynamic performance ( lift / drag ratio or L/D )?

    *Improving aerodynamic performance often comes at the expense of weight. This might be from additional span, advanced airfoils, span-loading, or more challenging integration ( i.e. engine and landing gear ). The weight control engineer should consider how the performance goals affect weight. Below is an illustration of setting performance goal relationships and examples of change agents that can warrant target redistributions:*



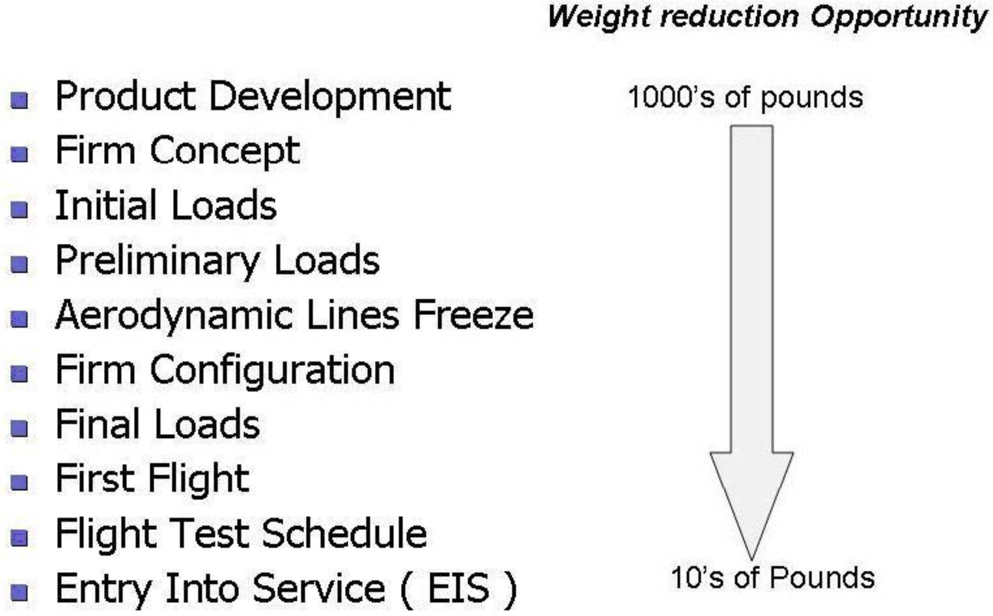
When establishing performance objectives, configuration lift/drag levels, maximum take-off weight, engine thrust, wing area, and operational empty weight must "all" be balanced. This entails many assumptions early in the product development process, translating into resultant performance goals for propulsion specific fuel consumption, vehicle lift /drag ratio, and operational empty weight. A significant factor will be the entry into service date. The fundamental question is whether sufficient time is allocated in the Program Schedule to warrant these performance objectives. Failure to consider the time element will result in downstream, costly changes to improve the weight situation.

<u>Example:</u>

- **Situation**: A*ssume the SFC and L/D goals are met and the program has reached the milestone that establishes external lines – the wing loft and planform, body cross-section and length are finalized.*

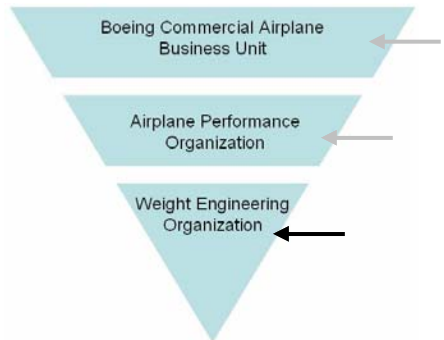
- **Target**: *Operational empty weight is 10,000 lb above the weight target.*

- **Proposal**: *Based on the geometrical constraints, the ability to remove thousands of pounds is reduced into the hundreds of pounds. The wing loads cannot be reduced by decreasing the wing span or altering the span-loading because high speed lines are firm. Weight Engineering informs Program Management that the OEW goal is unachievable in concert with the program schedule. In addition, the "achievable" OEW will be articulated with evidence to facilitate a program leadership re-plan.*




The Weight Engineering Organization ensures that the OEW goal is achievable given all the program constraints (cost, schedule, staffing resources, etc.). Again, if the L/D and SFC goals are realized, but the OEW required to meet fuel efficiency and range requirements are unachievable due to the airplane program constraints (cost, schedule, staffing, etc.), the Weight Engineering Organization will provide this information to Program Leadership. Airplane weight audits, by non-advocates, conducted throughout the airplane develop cycle ensure that all performance goals remain achievable and integrated as the design matures.

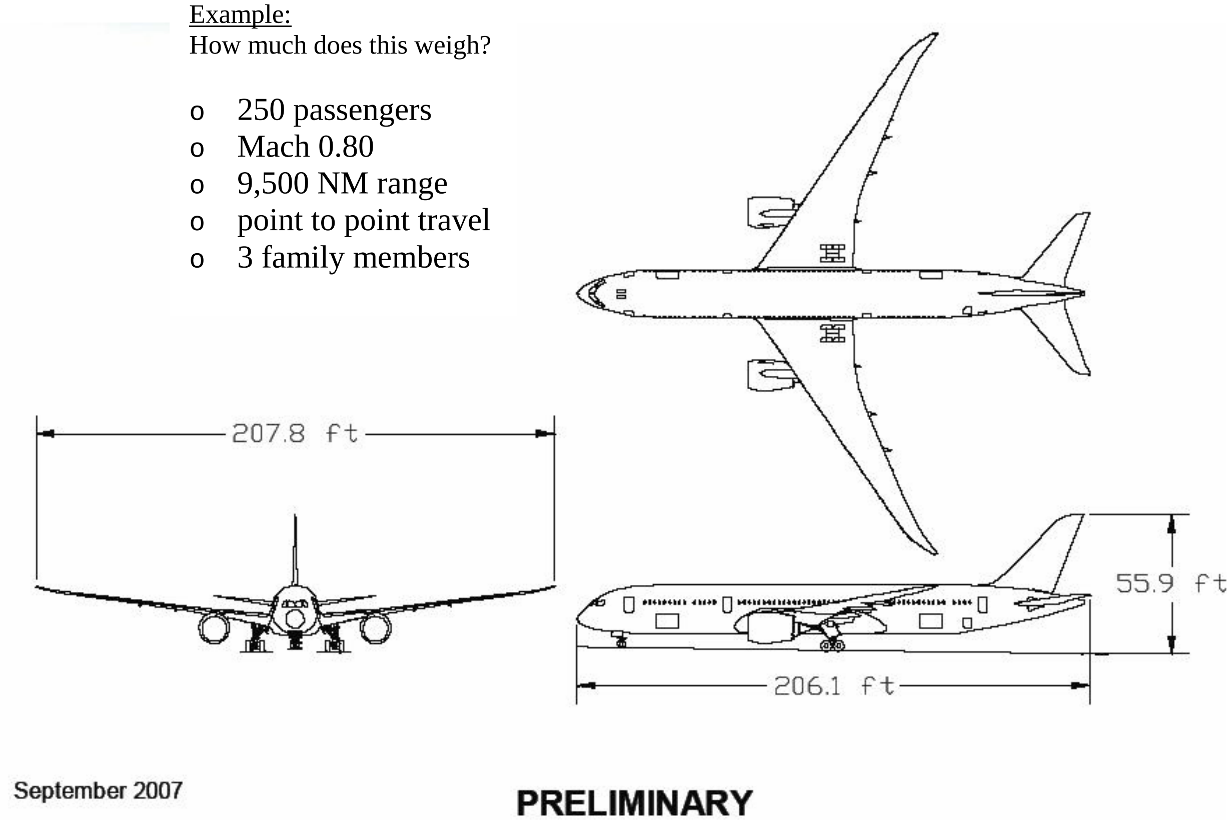
Now that the weight control engineer understands business unit's vision and the airplane performance requirements, they must determine how Weight Engineering "proactively" supports that direction/vision. Within the Weight Engineering Organization, the weight control engineer must develop a firm understanding of the organization's core competencies. How do the Weight Engineering Organization's core competencies affect the company vision?



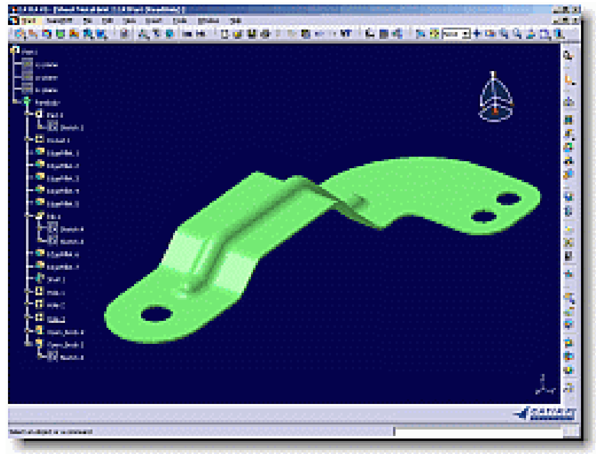

There are unique capabilities that enable the assurance of airplane weight efficiency, weight compliance, and loading flexibility of our company's products. These unique capabilities include providing an accurate airplane weight estimate given any level of definition. The definition could be an airplane 3-view (see Sept 2007 787-8 General 3-View) and wing planform with mission requirements.

<u>Example:</u>
How much does this weigh?

- 250 passengers
- Mach 0.80
- 9,500 NM range
- point to point travel
- 3 family members

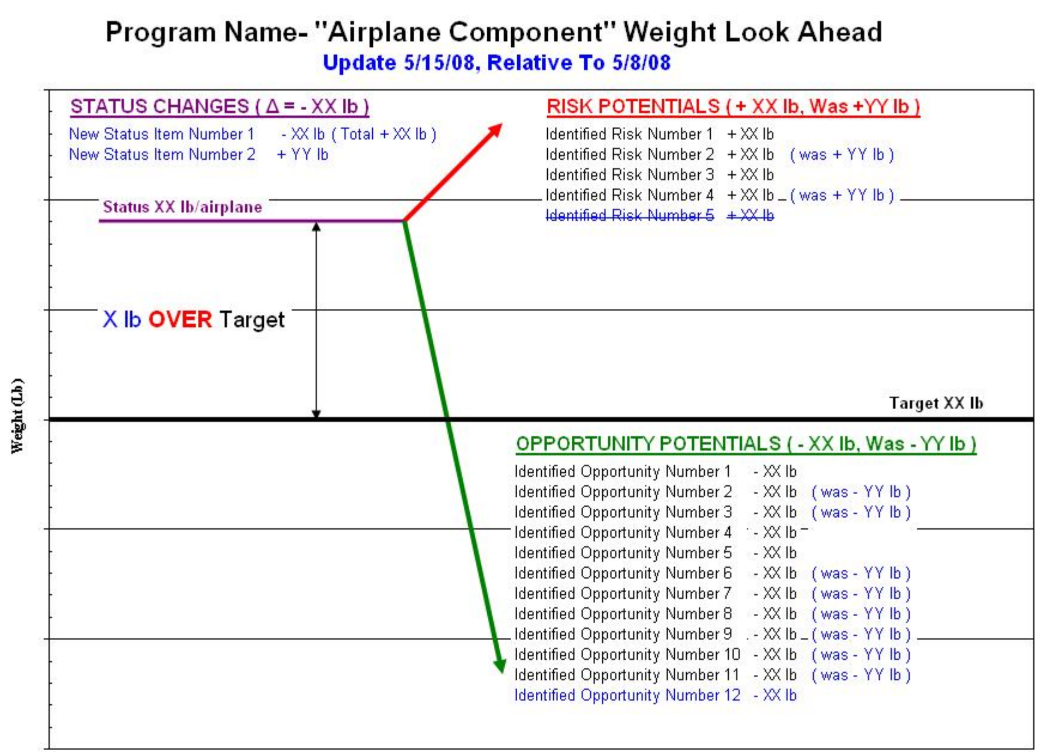


Alternatively, the weight control engineer could be given a complete parts list with computer model based definition.



In either case, the weight control engineer will be able to provide an accurate weight level based on sound judgment and assumptions or complete part level definition. The technical assumptions used to derive a weight estimate must corroborate the aerodynamic, propulsion and external loads assumptions. As new information becomes available, the assumptions must be re-evaluated and coordinated with the performance engineers.

The weight control engineer is required to provide the “fly away” weight level. The other unique capability that the weight control engineer has is the ability to “forecast” the vehicle weight from both a weight risk and opportunity perspective.



Forecasting potential weight risks requires an in-depth understanding of all design assumptions, which enables weight allocations for design maturity (known items not included in design sizing and unknowns based on previous model history). Generally, weight risks must be “actively” mitigated to avoid becoming a reality in the airplane weight level. The weight control engineer and design team must proactively seek and implement potential weight opportunities through conscious design changes. In addition to identifying opportunities, such as design optimization or material substitutions, a robust plan must be in place to see the opportunity implemented into the “released” design dataset. This is accomplished through communication and coordination with the design and leadership team on a recurring basis.

## 2) Teamwork

The second thrust, Teamwork, will focus on developing effective working relationships. The outcome of any successful Weight Management Plan is dependent on healthy working relationships. Developing a network requires the weight control engineer to understand who in the airplane program affects weight. A short list may include, but is not limited to the following:

- Configuration and Engineering Analysis
- Loads analysis
- Stress analysis
- Design
- Supplier management
- Program suppliers/partners
- Program management (first line to chief project engineer)

Therefore, it is necessary for the weight control engineer to establish rapport with the program leadership team, design community, supplier management, program partner/suppliers and the weight control engineering community. The weight control engineer must possess the skills to adapt to the personality of the culture, company, organization, and individuals. A strong sense of trust, dependability, and ethics is paramount for effective relationship building. Developing close working relationships goes beyond requesting and receiving information from customers and suppliers. Building personal relationships in the workplace facilitates:

- Mentoring opportunities
- Accessibility to design data ( gauges, parts lists, design presentations, assumptions, etc.)
- Improved communication /awareness with change activity from the design community
- New friendships

Relationships are fostered by providing accurate, on-time data and expertise – both written and verbal. Furnishing data on time and in an acceptable manner to the customer requires the weight control engineer to determine:

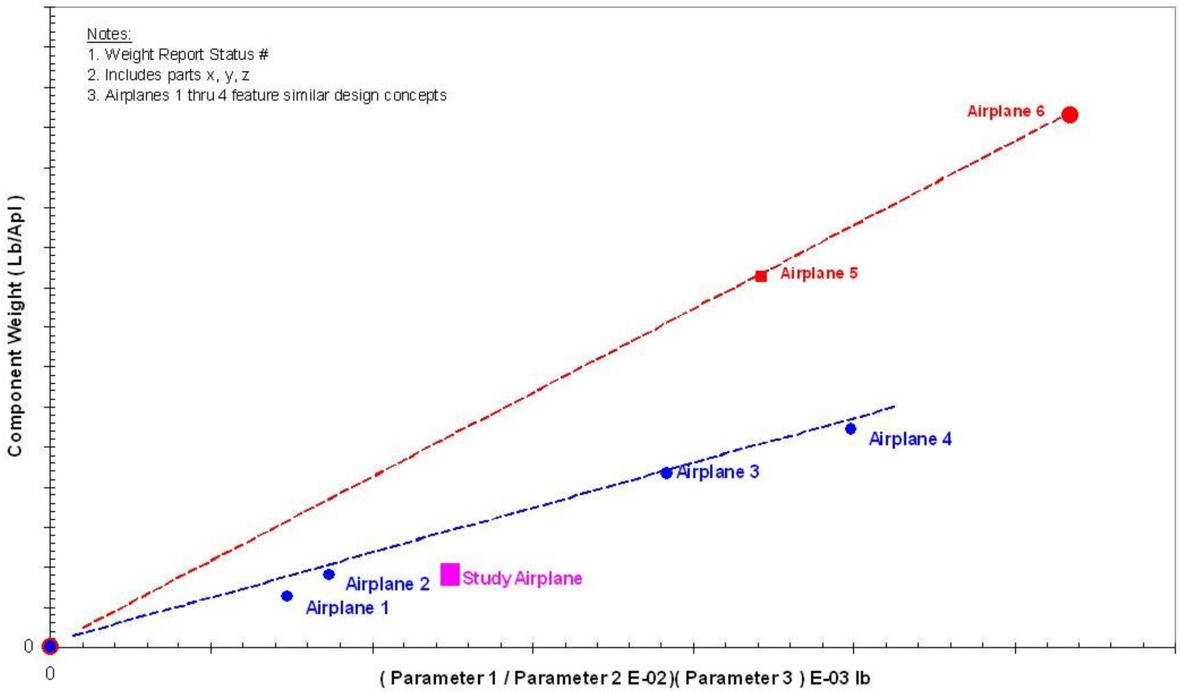
- What kind of data / information is needed?
- How the team will use the weight data?
- Why the data is needed?
- Who will use the weight data?

- When is the data required?
- What level of accuracy is appropriate?
- What particular format is required ( i.e. - interfacing with other tools )?

Answering the above questions equips the weight control engineer to decide how much fidelity and effort is required to provide the customer weight information ( sometimes referred to as the "5 minute, 5 hour, or 5 day answer" ). The amount of time to develop the weight data also indicates, in most cases, the fidelity of the estimate. The weight control engineer must have weight estimate "validation" methods to ensure the release of accurate data. Such validation methods may include:

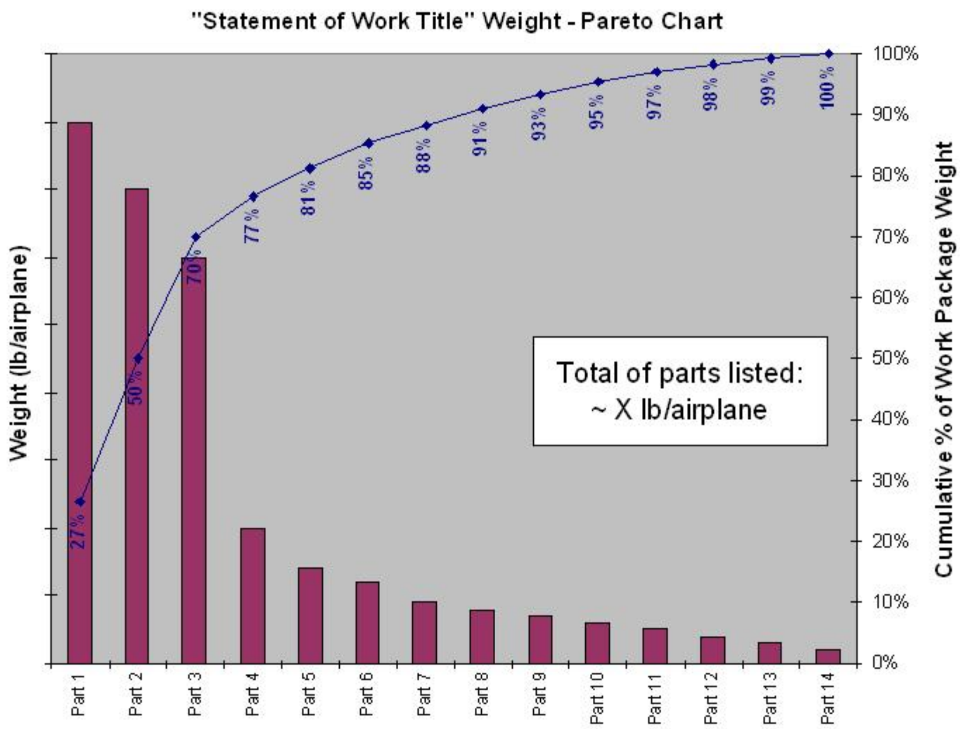
- Subject Matter Expert or Non-Advocate Reviews

- Tops-Down parametric charts ( determines efficiency and provides "sanity" check )

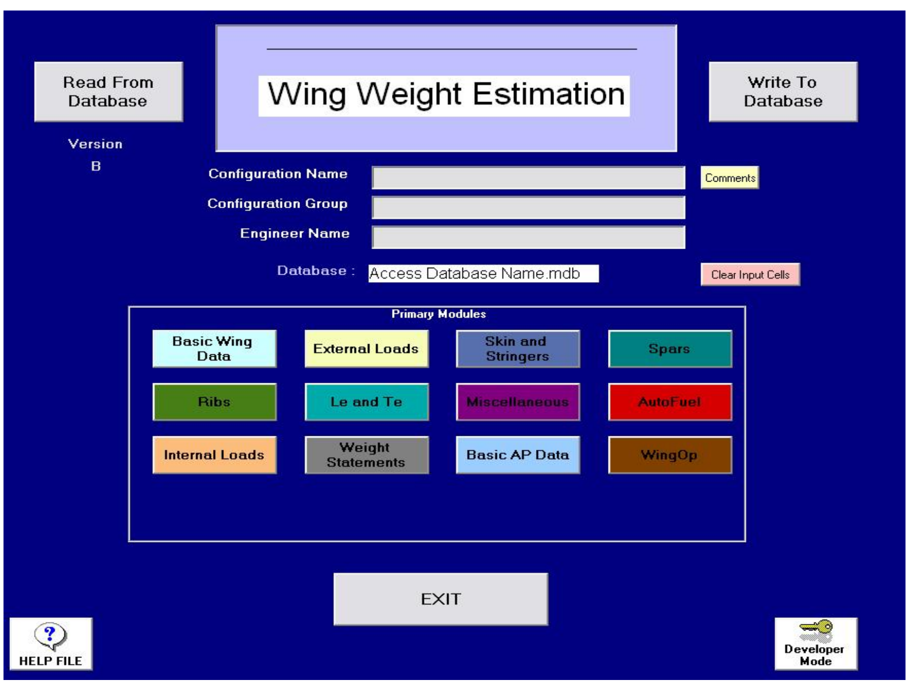



Tops-down or regression analysis can be used to focus weight reduction efforts as well as determine if components are optimized relative to previous models. When plotting study airplanes, it is imperative that the comparison is based on similar components. It should be noted that the study airplane is compared to "fully" released designs, which includes all necessary design constraints to be FAA/EASA certified. The study geometry will most likely not include such fidelity, thus considerations should be taken when discussing analysis results.

- Component level pareto charts ( focus weight reduction on heaviest parts )




- Component level weight estimation tools ( "design sensitive" algorithms that include: geometry, external/internal loads, material properties, stress sizing, layouts, etc. )



Teaming requires the weight control engineer to represent the airplane interests, not just weight control engineering's initiatives. When participating in the design process, weight control engineering must aide in finding design solutions for aerodynamic performance, producibility requirements, cost and schedule challenges, and customer expectations at the expense of additional weight. In addition, when conducting a trade study, the weight control engineer can serve as a facilitator – making sure all the appropriate disciplines are present at meetings. Teaming and communicating is essential and works both ways – not everyone can be present at all meetings all the time.

### 3) Technical Competence

Working effectively in the design process mandates the continual enhancement of technical proficiency. Our third thrust, Technical Competence, focuses on our core competence - always being able to articulate what the aircraft does weigh, could weigh, should weigh, and will weigh - given any level of airplane definition. Using these unique capabilities, the weight control engineer must articulate why it is important for the design team to pursue a "fully" optimized design.

During product development, the weight control engineer will make numerous assumptions based on previous experience and/or current fleet data, augmented to reflect new technologies the company is pursuing. Typically, during the early stage of product definition, cross-functional participation is minimal, resulting in the weight control engineer making many assumptions. Fundamental questions to pose when developing an initial airplane weight estimate include:

- What are the basic airplane mission requirements in terms of passenger count, range, speed, and family plan?

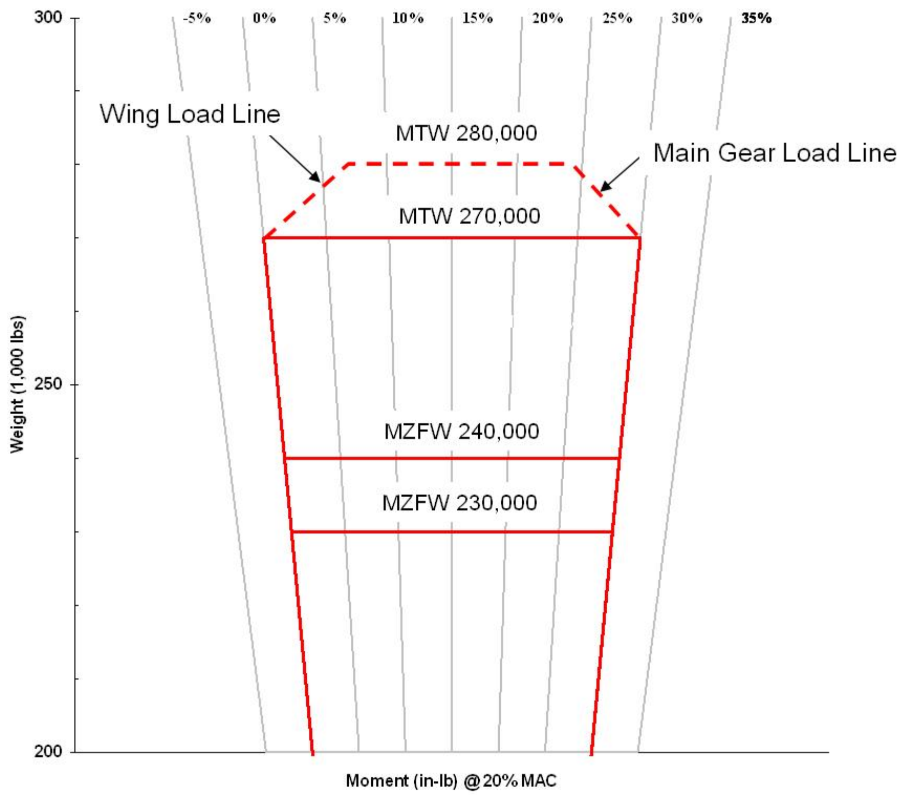
  *This will assist in assessing the cross-section and length of the passenger cabin, determining the wing area / span / sweep / and thickness, and addressing noise abatement. The family plan will influence the propulsion strategy.*

- Will the weight data affect performance guarantees? What part of the design development phase will the performance guarantees be given?

  *Authority to offer a new airplane to customers arrives well before part definition is available. Accuracy and unknowns must be considered and communicated. Growth allowances, based on past programs, should be included in the weight estimation.*

- How is loadability managed throughout the aircraft design cycle?

  *As the airplane progresses through the design cycle, if performance deficiencies arise, gross weight escalations may occur. Minimizing the workstatement via curtailed center of gravity limits can adversely affect the customer's loadability.*

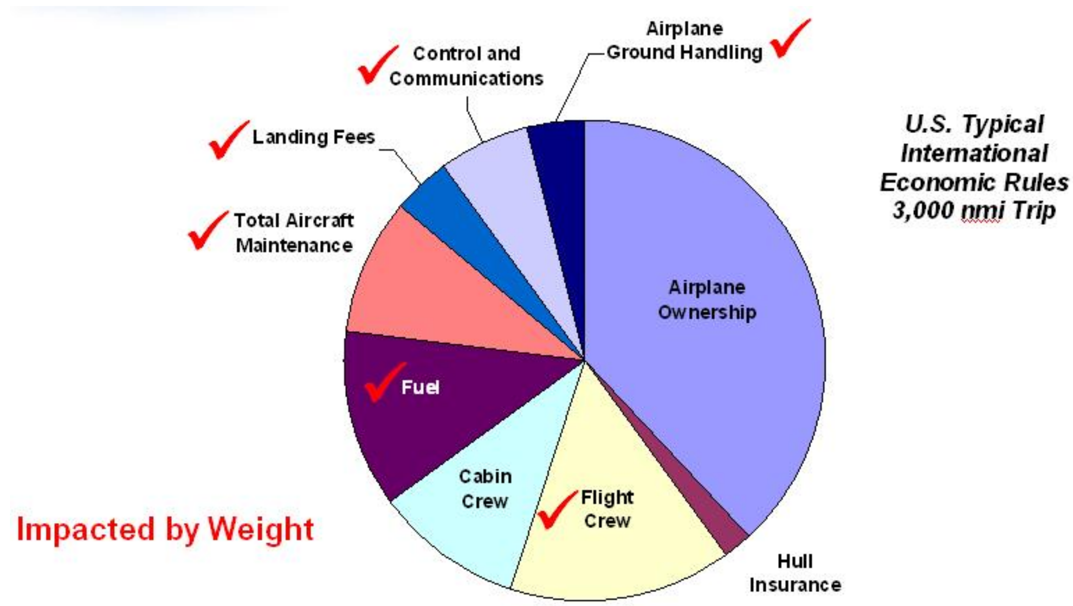



- For a given statement of work (i.e. wing, fuselage, systems), what are the primary design weight drivers?

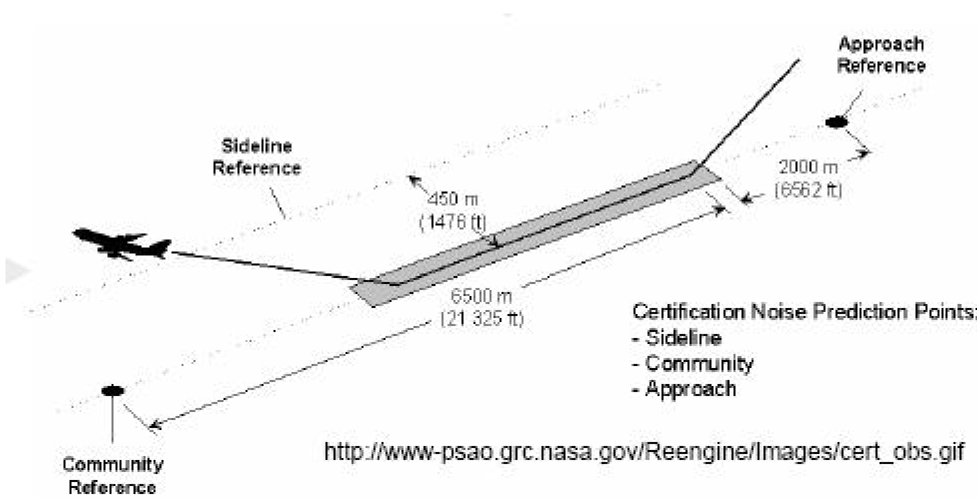
  - Material Selection ( Composite Fiber Reinforced Plastic or CFRP, advanced metals, etc. )
  - Planform Characteristics ( wing & empennage )
  - Airfoil technology ( maximum pressure distribution )
  - Wing High Lift Systems ( slat, krueger, flap complexity / fowler motion / deflection )
  - Load Alleviation ( active or passive )
  - Component Architecture ( skin-stringer, honeycomb, multi-spar )
  - Fuselage ( cross-section shape, # aisles, cabin altitude, cutouts )
  - Integration ( engine location, landing gear support location, load path )
  - Cost of Manufacturing drivers that compete with weight

The weight control engineer must gain an understanding of design, manufacturing, and material requirements and processes to gain proficiency in design and analysis applications. Practical application of acquired technical knowledge will maximize weight efficient design that satisfies program requirements and objectives. The weight control engineer must be able to ask design related questions while challenging decisions and criteria. Challenging decisions and/or requirements could include inquiries such as:

- What requirements are driving the design?
    - Company Criteria ( Design Requirements and Objectives )
    - Regulatory Agencies ( FAA, EASA, JAA )
    - Economics ( Fuel Burn, Total Airplane Costs )




    - Noise Certification ( Impacts takeoff and landing performance, propulsion, etc.)



- Environmental Issues

  **SEATTLE, Sept. 28, 2007** -- Boeing [NYSE: BA], Air New Zealand and Rolls-Royce today announced a Memorandum of Understanding to conduct a biofuel demonstration flight designed to help accelerate the development of viable and sustainable alternative fuels for commercial aviation uses. Boeing is exploring second-generation biofuel feed stocks and processes that have the potential to reduce greenhouse gases throughout their entire lifecycle.

  **HOUSTON, March 13, 2008** -- Continental Airlines [NYSE: CAL], Boeing [NYSE: BA] and GE Aviation [NYSE: GE] today announced plans to conduct a biofuels demonstration flight in the first half of 2009 in an effort to identify sustainable fuel solutions for the aviation industry. Continental is the first major U.S. carrier to announce plans to highlight technological advancements in sustainable biofuels that can help to further reduce carbon emissions.

- Design Life (Higher Design Service Objective can affect fatigue sized parts)

- Design for Manufacturing

  **SEATTLE, April 14, 1998** -- Using advanced design and manufacturing techniques that enhance affordability and product quality, Boeing has completed the detail design of major forward fuselage components for the two Joint Strike Fighter (JSF/X-32) demonstrator aircraft. Fabrication of those components is now underway.

- Production Rate

  **SEATTLE, Nov. 08, 2006** -- The Boeing Company [NYSE: BA] has started using a moving assembly line for the first time to build its market-leading 777 jetliner.

  Earlier this year, Boeing began work to transform its 777 assembly line into a leaner and more efficient production system. This initial use of a moving line during final assembly represents substantial progress with that transformation effort.

- Does the “Family Plan” design philosophy cause resultant commonality and drive weight into other family models? If the largest member of the family is point designed, then the smaller models may have additional capability not required for the mission (i.e. larger wing planform, which equates to excess fuel capacity).

- Does a stable Research and Development investment stream exist to advance technology compatible with budgetary and schedule constraints?

    - Material application ( composite versus metallic primary structure )
    - Metallic alternatives ( titanium / aluminum / steel )
    - Aluminum ( 7000 versus 2000 series aluminums )
    - Producibility or Manufacturing constraints
    - Fasteners ( size, grip length, availability, allowables )
    - Airline maintenance and inspection requirements
    - Facility floor space ( new equipment, larger components, rate )

Proceeding through the design process, more cross-functional support becomes available. The weight control engineer transitions to a detail design perspective. Primary emphasis becomes architectural ( i.e. stringer shape, solid laminate vs. sandwich construction, etc. ) coupled with extensive load conditions and margin of safety information. Some general information to collect for structures or systems statement of work includes:

- Detail Parts
    - Identify “primary” structure and any sizing constraints
    - Identify “secondary” structure and any sizing constraints
    - Identify “integration” structure and understand how it affects the integrated design ( splices vs. bonded structure, sealant, fastener type & size )
    - Differences in attachment concepts ( bolts or rivets )

- External Loads
    - Identify dominant conditions
    - 2.5G flaps up, 2.0G flaps down, dynamic gust, etc.

- Internal Loads
    - Identify dominant cases
    - Buckling, combined loading, thermal, etc.

- Materials
    - Allowables (s-basis, b-basis, allowable reductions or knock-downs)
    - Density (areal weight vs. density, etc.)
    - Sizing Criteria ( choosing the most efficient material for strength, fatigue or durability )
    - Application ( CFRP, ply orientation, etc.)

Possessing technical competence aided by excellent communication skills yield authoritative influence with the design team. Providing clear, concise explanations of weight impacts along with design alternatives will build credibility. It enables a platform from which the weight control engineer can offer alternate solutions that may be more weight efficient.

**4) <u>Personal Attitude / Challenge / Development</u>**

Finally, it is important to have the perspective it takes a lengthy period to become an adept weight control engineer. Developing weight control attributes takes repetition working through new designs. Learning to be inquisitive, while providing appropriate support, is necessary. Asking "why" and "how" the design has changed are fundamental attributes that will enable a weight control engineer to influence the design. Continually seeking the reasons for design change is challenging, within an "Airplane Program" environment, due to the busy nature of the process. Having a positive and optimistic outlook and approach can enable more cross-functional participation resulting in accumulation of known and unknown information - yielding support and buy-in of mass property estimates.

Communicating skillfully is an essential asset; hence, verbal, written, and presentation materials manifest excellence to the particular audience. The ability of the weight control engineer to affect the airplane weight level throughout the development cycle also depends on their ability to communicate effectively. Providing clear, concise written and verbal communication affects trade study choices, configuration updates, as well as schedule and cost decisions.

Verbal communication at the desk of a design member can provide valuable information, future mentor relations, recommendations, and validation of design assumptions that affect the weight estimate. The weight control engineer approaches this conversation by recognizing the need to:

- Establish design team working relationships - trust, integrity, ethics
- Engage discussion about design requirements & hardware, etc.
- Discuss any recent changes, criteria, assumptions, etc.
- Formulate questions / challenge decisions as appropriate
- Demonstrate pro-active design team participation
  - Initiative & Creativity
  - Technical Leadership
  - Communication
  - Problem Solving Capability

A key element of any Weight Management Plan involves weight visibility through written communication. Written communication requires the weight control engineer to articulate exactly what is changing and why. This can be difficult if the current weight estimate is not well understood and documented. When considering a weight change description, the weight control engineer should consider the following questions:

- What is causing the design and/or analysis change?

  *Choose the appropriate action when trying to answer this question ( i.e. is the part gauge <u>increasing</u>, <u>decreasing</u>, being <u>strengthened</u>, assumption <u>corrected</u>, etc.? )*

- What “specific” part of the airplane is changing?

  *Be specific – i.e. wing box upper panel skin, vertical tail inspar ribs, stow bin, wing spoiler actuator, spar, horizontal tail leading edge skins, etc.*

- Quantify the design changing ( i.e. skin gauge from 0.120” to 0.080” )
- What new information became available to substantiate the change?

  *This might occur because of revised design loads, improving integration between parts, removing a second layer of primer, etc.*

  *Example:* *Increase the number of wing leading edge slats from 6 to 9 to reduce the landing approach speed by 1 knot.*

Supporting trade studies is another avenue requiring clear communication. Typically, trade studies are disconnected to the baseline configuration vehicle. The baseline for the trade study is not necessarily the configuration baseline. When participating in a trade study, the weight control engineer must clearly differentiate between the configuration baseline, the trade study baseline and the trade study alternative(s). This occurs because of the dynamic nature of product development. The Airplane Configuration Definition is updated at defined periods- sometimes only twice a year. This lag time results in numerous changes accumulating for the next airplane configuration baseline update. This represents a fundamental reason for differing baseline interpretations – mandating the weight control engineer to clearly understand and facilitate clear communication. Cross-functional communication is mandatory for a successful design and trade study. Consider the following approach:

1. Gather design data
   - Design criteria, layouts, loads, sizing, etc.
   - Identify what is known (criteria, references, etc.)
   - Identify what is <u>not</u> known (may be more important than what is included)
   - List assumptions

2. Analyze baseline and alternative(s) using equivalent methodology ( cross-functionally ) and apply weight change to baseline. Avoid using different design techniques to the trade study options because it may yield misleading results. Use the same analysis approach for both baseline and alternate design. The weight control engineer must investigate how supplied design data was developed to ensure consistency.

3. Prepare verbal message
   - Determine specific message for each chart (i.e. what message must the audience receive)
   - Ensure message is tailored for the correct audience (senior managers, technical community, etc.)
   - Dry run if necessary
   - Anticipate question(s)
     - Prepare back-up charts

4. Assemble visual aids
   - Each visual aid chart should contain a stand-alone message
   - Tailor the message to the specific audience (senior managers, technical community, etc.)
   - Consider room size and technology ( view-foil or electronic )
   - Choose appropriate chart type(s)
     - List of Attributes
     - Key message using words ( bullet chart )
     - Bar/Graph
     - Weight Tracking focused on physics as opposed to entity
     - Waterfall chart denoting significant events ( weight vs time )
   - Consider labeling – proprietary, font size, etc.
   - Consider issues & concerns
   - Concluding message

5. Critique material (both verbal & written)
   - Sufficient information?
   - Can the message be misinterpreted?
   - Apply "plan, do, check, act" principles

6. Consider a Dry Run involving individuals such as Peers, Lead Engineer, Subject Matter Experts, or 1st Level Supervisor. This aids the weight control engineer toward developing credibility, command of subject, and authoritative effectiveness.

The weight control engineer should be continually improving capabilities through both formal and informal training. Another facet of personal development includes nurturing mentoring relationships. Implementation of short and long-term development plans needs to occur early to ensure proper steps are taken to achieve goals. Short-term plans may include specific assignment needs as well as specific training (CAD classes, structures or aerodynamic classes for new hires taught by Company personnel, attending conferences such as SAWE). Long-term plans may include job rotation outside of their primary discipline within the company, or a specific program path (management or technical). To ensure goals are realistic and obtainable within a given period, consultation should occur with both the lead engineer and first level supervisor.

## Conclusion

The attributes, principles, and suggestions outlined in this paper are offered to foster effective participation by the weight control engineer in the design development process. This takes time and repetition to become second nature. The questions asked in each section are a starting point for developing a better understanding of the weight control engineer's work statement, to improve technical capability by acquiring more detail design knowledge, and provide an extended network of resources for future reference.

The weight control assignment allows the engineer to interface with many cross-functional disciplines, enabling more education opportunities. In addition, often the weight control statement of work is at a higher level than one major component or system ( i.e. wing box vs.

wing panels, fuel system vs. fuel pumps, etc.). Interfacing with other organizations throughout the design development provides the new employee exposure to more of the airplane or project allowing the weight control engineer to provide design guidance across team boundaries.

A large portion of this paper focuses on the weight control engineer's ability to communicate. Mastery of this attribute must be a primary focus. Look for mentors with strong communication skills and a general "joy" for the job.

Above all, the weight control engineer should enjoy the journey, recognizing their efforts contribute toward the creation of new and efficient transportation vehicles. If you are enjoying your contribution to the company, acquiring the necessary skills and attributes will follow.

## Acronyms

BCA – Boeing Commercial Airplanes
SAWE – Society of Allied Weight Engineers
SFC – Specific Fuel Consumption
OEW – Operation Empty Weight
L/D - Lift / Drag Ratio
FAA - Federal Aviation Administration
EASA – European Aviation Safety Agency
JAA – Joint Aviation Authorities

## References

All graphics were acquired via the World Wide Web or created by the author. All Boeing pictures were obtained from the external website and approved by communications department for release.

[1] Scharfenberg, Thomas G., Internal Boeing Weight Engineering Document, "Vision for Weight Control", Everett, Washington, 2007.

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**Biography**

Ken is currently a lead engineer in the Boeing Commercial Airplane Weight Engineering Organization. He received his Bachelor of Science degree in mechanical engineering from Washington State University in 1996. He began his career at Boeing in 1996 assigned to Payloads Weight Control responsible for 737 Next Generation and 777 stowage bins. In 1998, he was responsible for the weight efficiency of the 767-400ER New Look Interior.

In 1999, Ken was assigned to Structures Weight Control, supporting 747X new wing development - participating in many alternative wing planform optimization studies. Subsequent work assignments included the Sonic Cruiser and early 7E7 product development. In 2003, Ken was selected to lead the 787 Wing/Landing Gear/Empennage weight control team. His current assignment resulted in spending numerous hours educating both new hires and industry partners who had little or no understanding of the weight control function. This was the motivating factor behind this paper. This is his first SAWE paper.

Ken is married and has three young children. Outside interests include attending and participating in church, spending quality time with his wife and children, and playing sports with family and friends (golf, basketball, softball, snowboarding/wakeboarding, fishing, etc.).