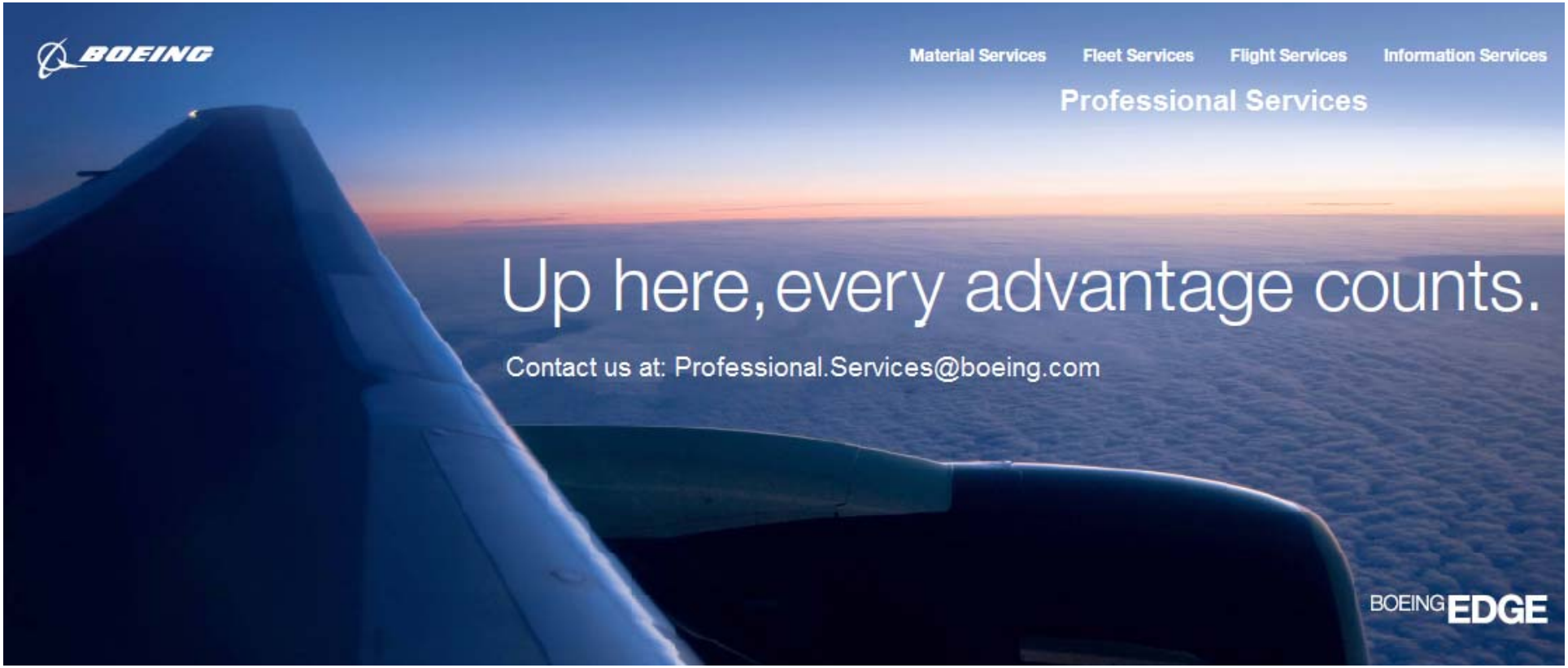

Aircraft Weight Error:
Impacts of Planned & Real Errors

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What Do We Mean By Weight Error?

- **Most commercial passenger flights are planned with incorrect Zero Fuel Weight (ZFW)**
  - Flights are planned several hours before departure
  - By departure time, no-shows, actual checked baggage, and belly cargo may be quite different from what was planned
- **Most passenger flights are planned with inaccurate passenger/payload weights**
  - We don't weigh the passengers. We only estimate weight.
  - Different countries have different "standard weights". Are they realistic?
- **We are talking about two separate problems: one of planning weight and one of true weight? Do either of them matter?**
  - The industry has long taken the approach that "the plane knows how much it weighs"
  - The laws of physics govern how much fuel the plane burns from what it truly weighs, in spite of how we planned it or what we *thought* it weighs

But, Many Direct & Indirect Costs of Both Real & Plan Error

So What Does Weight Actually Cost To Carry?

- **What is the incremental burn for extra weight?**
  - ~3% per flight hour to carry incremental weight
  - It is the same on a narrowbody or widebody aircraft
    - Only affected by engine technology: improving over time
    - Turboprops cost much less
- **The typical airline**
  - 3,000 – 4,000 flight hours per aircraft per year
  - Assume 2015 fuel price US$2 / gallon = € 0.62 / kilo

=

US$7,000 / Year / Aircraft

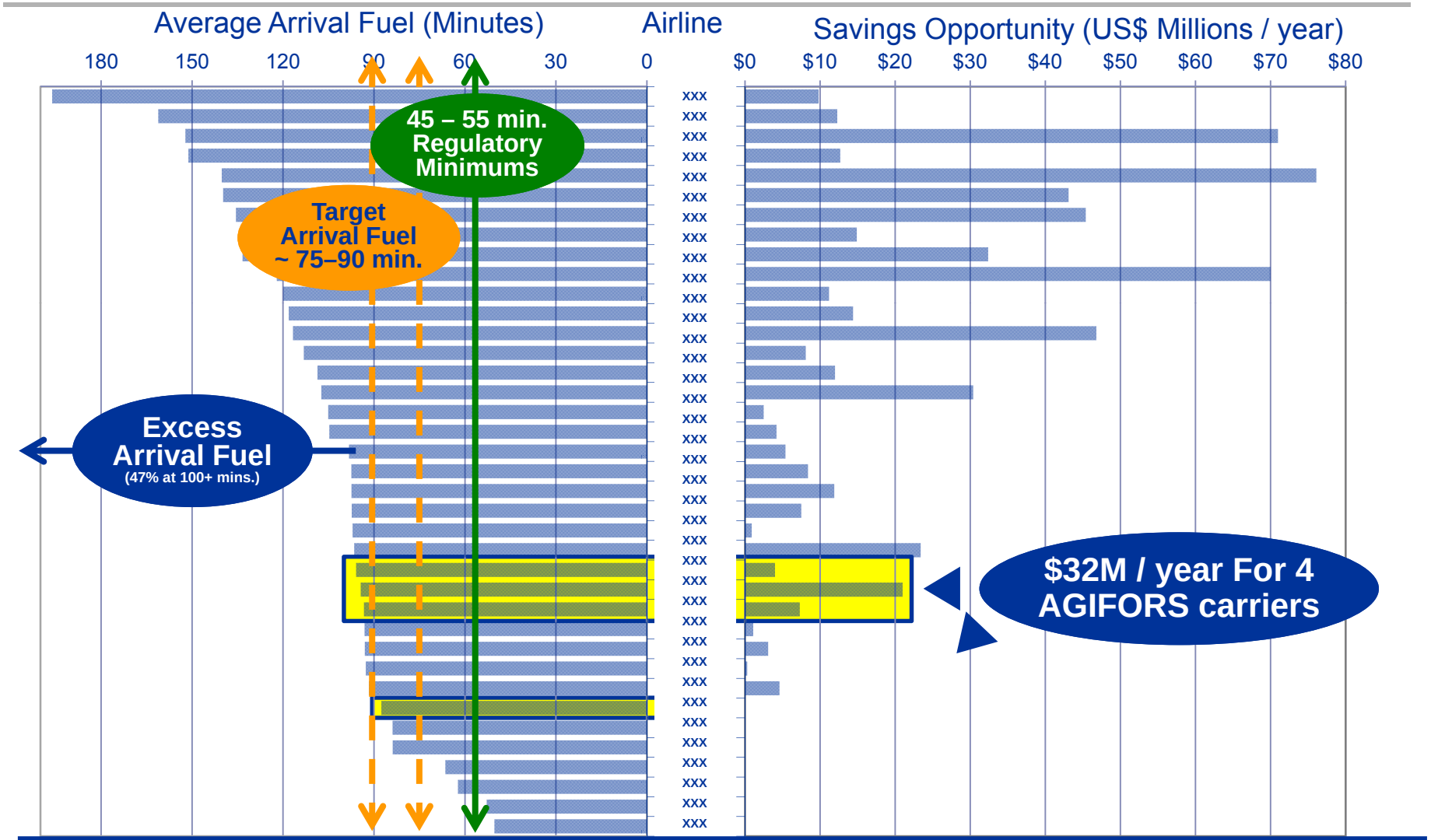
Excess Weight Costs Airlines Millions

Direct Effect of Planning Error

- **Airlines typically do not re-plan flights if the ZFW falls off between the time of the initial flight plan and flight close-out**
- **A 5-10% no-show rate could produce a variance of 300 kgs. in fuel burn between planned trip fuel and actual**
  - Initially appears to be a savings, because less weight = less burn
  - Over time creates doubt & uncertainty in the accuracy of flight plans
- **ZFW variances compound into altitude variances, which in turn produce time variances, from the pilot flying the FMC, and the difference between FMC burns & altitudes vs. the flight plan**
- **Over time, mistrust of flight plan accuracy leads to extra fuel requests and longer alternates**

Mistrust Is The Key Cause of High Arrival Fuel

The Cost of Excess Arrival Fuel



Savings opportunities likely > $200M across conference participants

Source: Boeing AHM (1/1/12 – 8/15/12); 500,000+ records

Fundamental Passenger Payload Issue

- **FAA Passenger Weight Standard**
  - 79 kgs. / pax + 7.3 kgs. hand luggage = 86.3 kgs. (summer)
  - 81.3 kgs. / pax + 7.3 kgs. hand luggage = 88.5 kgs. (winter)
- **Some countries follow same standard, many nations have their own**
  - EU: 82 kgs. / pax + 6 kgs. hand luggage = 88 kgs.
  - Mexico: 74 kgs. / pax + 6 kgs. hand luggage = 80 kgs.
  - Brazil: 70 kgs. / pax + 5 kgs. hand luggage = 75 kgs.
- **Worldwide trend is for more passengers to carry their luggage onboard instead of checking it**
  - In U.S. this trend highly accelerated due to charging for all checked baggage
- **Additional worldwide trend – people are getting heavier**

Passenger Payload Issue: Carry-On Baggage

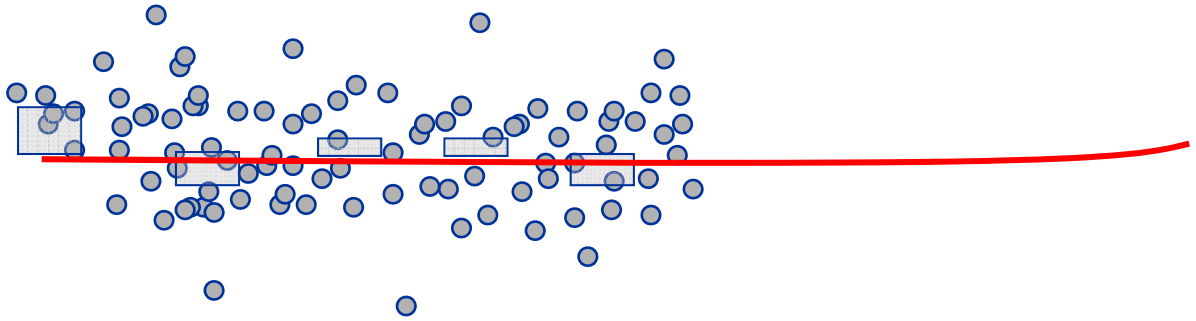
- **A typical businessman's hand luggage:**
  My own –
  It weighs 20 kgs. –
  A little more than the standards!

E190 Bin

- **So what effect does extra hand luggage weight and heavier passengers have on the total aircraft weight?**
  - Consider the multiplier effects …
    150 seat narrowbodies …
    300 seat widebodies …

Additional Indicators of Weight Error

- **The scatter in a diagram of aircraft "deterioration" factor**



- **Seasonality in "deterioration" factors observed by many airlines**
- **Boeing's experience with Entry Into Service (EIS)**
  - Aircraft have "book" performance on delivery flights and airline proving flights
  - Several months after EIS, airlines report a rapid "deterioration" of up to 3% …

A Payload Increase of 2,400 kgs. Increases Fuel Burn by 3% on a 500 nm 737 NG Flight – the 737 In-service Fleet Average

Weight Error vs. Real and Likely Deterioration

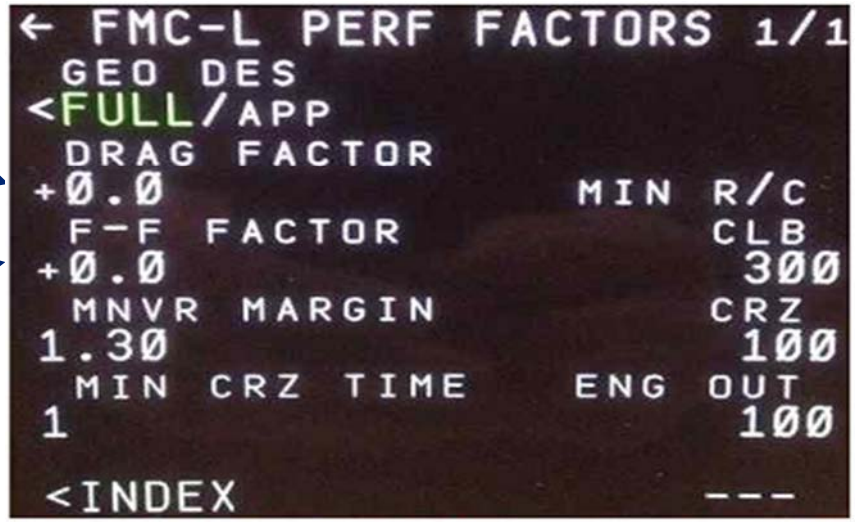
- **Aircraft deteriorate over time, but not at the rates often measured by performance software**
- **Very little deterioration in first two years**
- **Typical deterioration at 6+ years**
  - ~0.5-1% possible typical drag effects from age, patches
  - ~0.5% likely weight issues from condensation (insulation blankets) and dirt
    - An important reason to do periodic empty aircraft weighings
  - ~0.5% possible rigging
  - Deterioration possibly due to engine wear & tear
    - Cyclical, corrected by scheduled engine maintenance
- **At 6+ years, true deterioration likely ~2.5%**

Additional "Deterioration" Likely Due to Weight Error

Deterioration, the FMC and Phases of Flight

Drag
(usually set to 0)

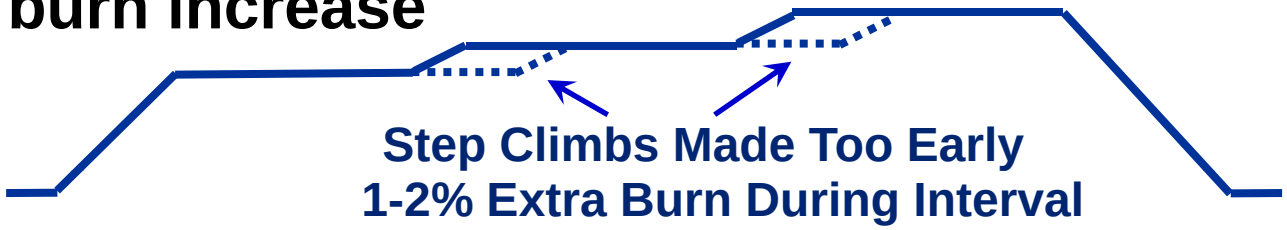
Fuel Flow



Engine, drag & payload error impact different elements of the flight

The Effect of Incorrect Weight on Fuel Burn

- **The FMC will recommend an optimum altitude that is slightly higher than optimum, which produces an fuel burn increase**



- **The resulting overburns will be highly variable due to the variability of load factors and the seasonality of weight errors**
- **The Fundamental Law of Flight Planning: Fuel and time calculations must be accurate**

BOEING EDGE

A Graphical View of Altitude's Impact on Burn

What Do Airlines Do About Weight Error?

- **Comply with their Civil Aviation Authorities weight standards**
- **There is a fear that thoroughly studying the passenger weight issue will result in more weight-restricted flights**
  - A risk on hot & high departures or very long legs
- **But airlines need to be aware that incorrect weights cost money on *all* departures**

In Summary …

- **Yes, the airplane knows how much it weighs**
- **But the Flight Management Computer (FMC) does *not* know how much it really weighs**
  - It only knows what you tell it
- **If the ZFW typed into the FMC is based on incorrect payload weights, the aircraft will make incorrect step climbs and also burn more fuel**
  - There will also be unexplained variances in fuel burn due to differences in Load Factor
- **If the ZFW typed into the FMC (from the Load Sheet) does not match the Flight Plan, there will be fuel burn variances**

Fuel Burn Variances Cause Pilots to Distrust the Flight Plan
Distrust of the Flight Plan Causes a Gradual Rise in Arrival Fuel
Excess Arrival Fuel Costs $$$$$$$$$$$$$$$$$$$

Thank You!