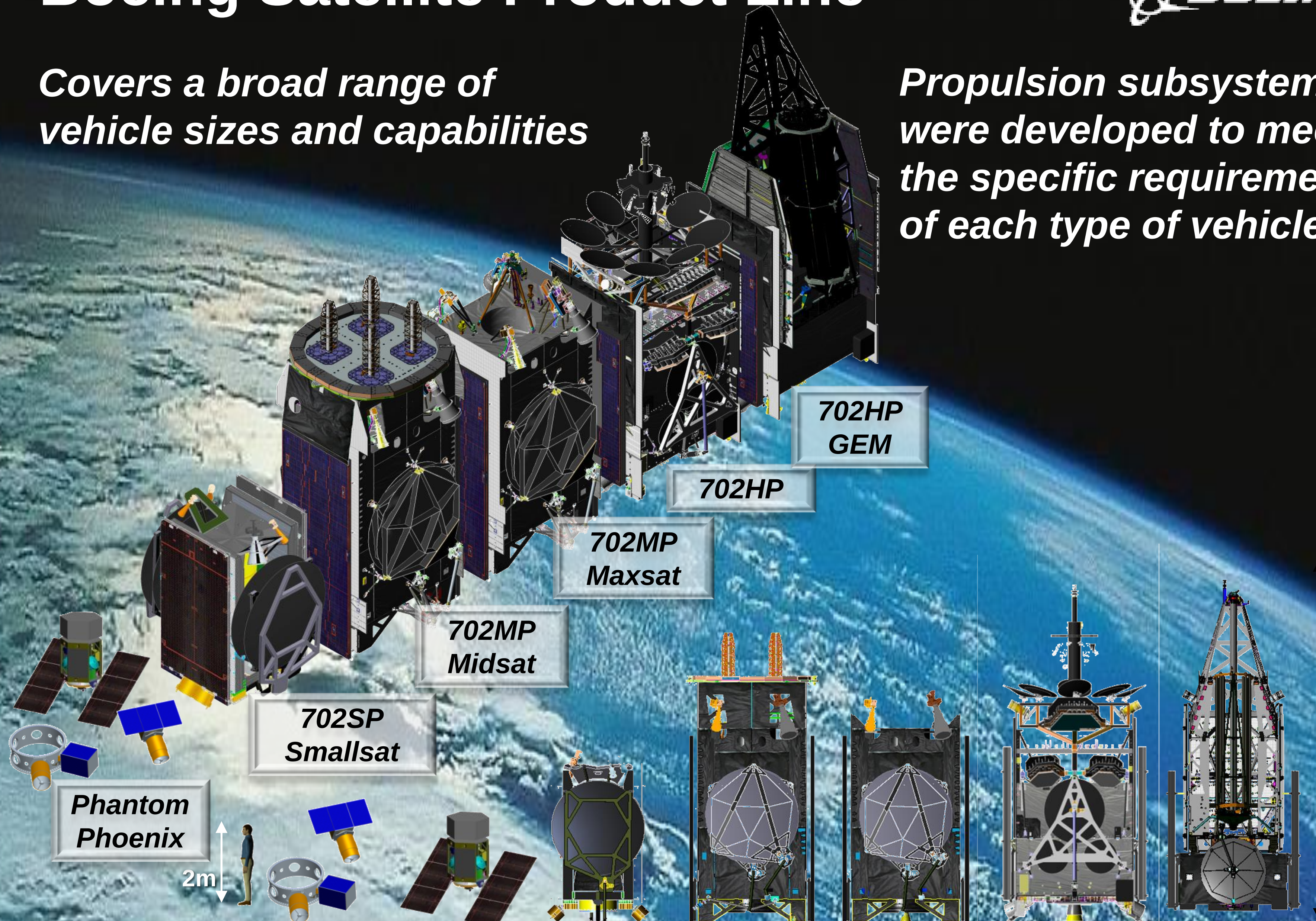
# The Future of Satellite Propulsion

**Kurt Kreiner**
**Chief Engineer & Boeing Technical Fellow**
**Bus Products**
**Boeing Defense Systems**

# Boeing Satellite Product Line

*Covers a broad range of vehicle sizes and capabilities*

*Propulsion subsystems were developed to meet the specific requirements of each type of vehicle*

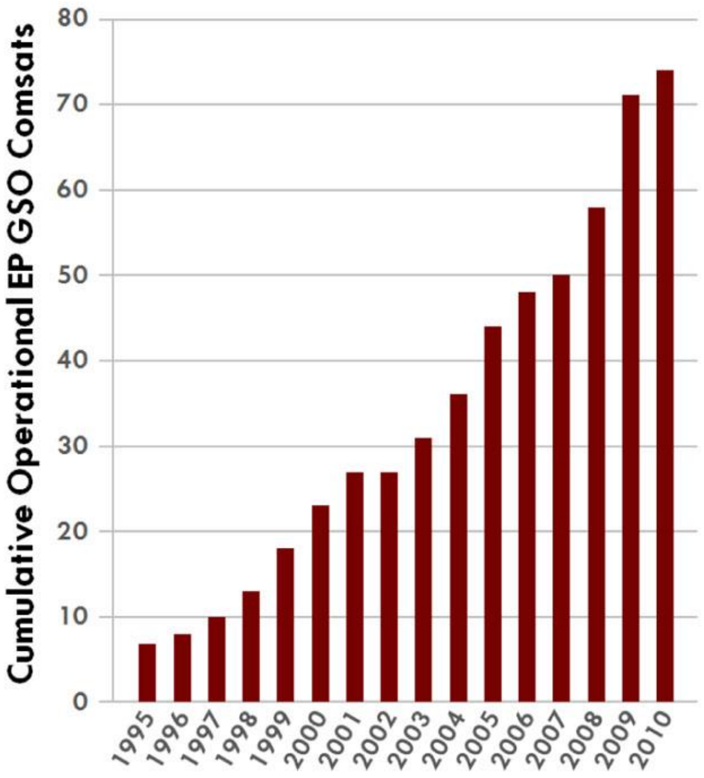



| Payload Power (kW) | 0.5 | 1.3 | 3.7 | 6-10 | 10-12 | >12 | 8-10 |
|---|---|---|---|---|---|---|---|

# Propulsion Subsystems

- **Boeing's current propulsion subsystems cover a very broad spectrum**
  - **>100 products**
  - **>10 major suppliers**
  - **Six different configurations**
    - **N2H4 monopropellant (376, GPS)**
    - **NTO/N2H4 dual mode (702 MP midsat)**
    - **Hybrid NTO/N2H4 dual mode and arcjets (702 MP maxsat)**
    - **NTO/MMH bi-propellant (393, 376, 376W, 601, 601HP, 702 GEM)**
    - **Hybrid bi-propellant and xenon ion propulsion (702HP)**
    - **All electric xenon ion propulsion (702SP)**

Figure 1: Historical Growth of Satellite EP for Station-Keeping [3]




**Subsystems design trends continue towards EP solutions–**
**Provides the maximum performance**
**Industry trend shows a 10 X increase**

# Macro Assessment of Satellite Propulsion in the Future

- **What are the key drivers for the future satellite propulsion subsystems?**
  - **Flexibility**
  - **Performance**
  - **Cost**
  - **People**

# Propulsion Subsystem Flexibility

- Flexibility
  - Spacecraft mission requirements
    - Payload capability & performance
      - Maximum capability for a given separated mass
      - Need to provide accurate pointing performance
    - Launch vehicle capability
      - Must maximize the capability of each launch vehicle
    - Spacecraft life
      - Needs to meet the customer requirement with margin
    - Incremental improvements in reliability
  - Customer preferences and experiences
    - Subsystem needs to be user friendly
    - Technology must be sufficiently matured



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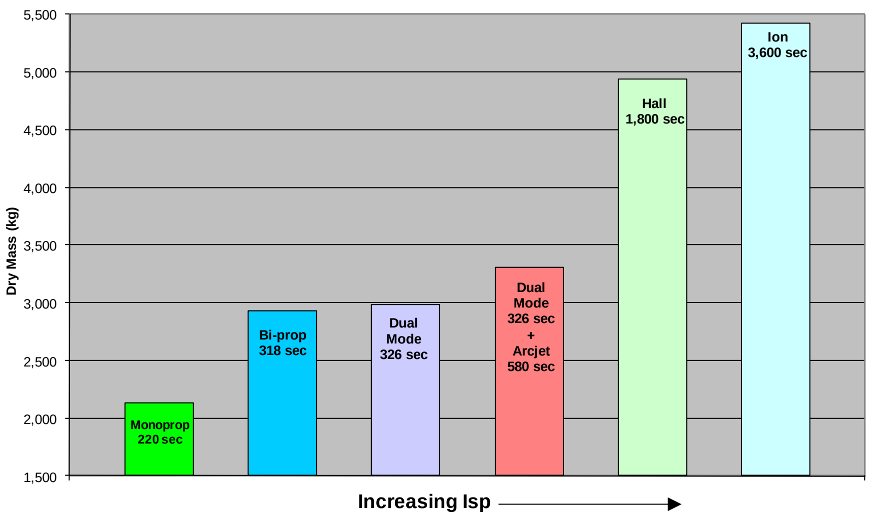
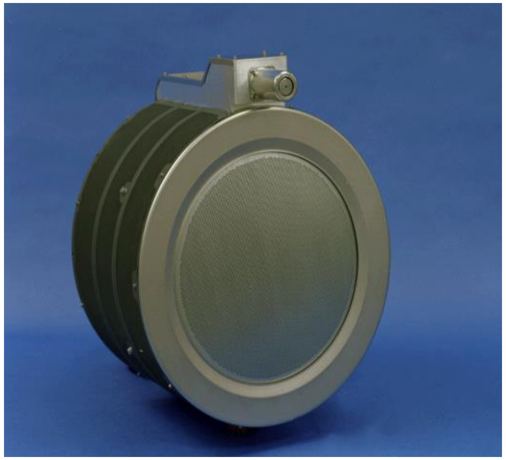
# Propulsion Subsystem Performance

– **Performance**

- **Most satellite propulsion technologies have achieved a high level of maturity and flight experience**
- **Future plans:**
  - **Higher performance for lower subsystem weight**
  - **Most efficient thrust to power**
  - **Increased capabilities**

**GEO S/C Drymass vs. On-borad Propulsion Isp**
**Ariane 5**



**Performance optimization is now the key**

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# Propulsion Subsystem Costs

- Cost 3
  - Competitive satellite market place require:
    - Lowest possible unit recurring costs
    - Lower unit non-recurring costs for product up grades, changes and qualifications
  - Financially strong suppliers
    - Supplier base continues to shrink over time
    - Competitive environment reducing



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# People – Future Propulsion Engineers

- **There is no future satellite propulsion without the people with the knowledge, skills and experience to make it happen**
- **Based upon the United States Bureau of Labor Statistics May 2012 data:**
  - **Project job growth in the U.S. from 2010 to 2020 for aerospace and mechanical engineers is expected to grow by 7.8%**
    - **From 323,620 to 349,020 positions**
- **Engineering job growth numbers do not account for:**
  - **Work force attrition due age demographics**
  - **Loss of engineers to jobs outside engineering and science professions**

# Work Force Demographics

- **Additional positions needed to be filled with up to 50% (161,810) of the work force eligible to retire now**

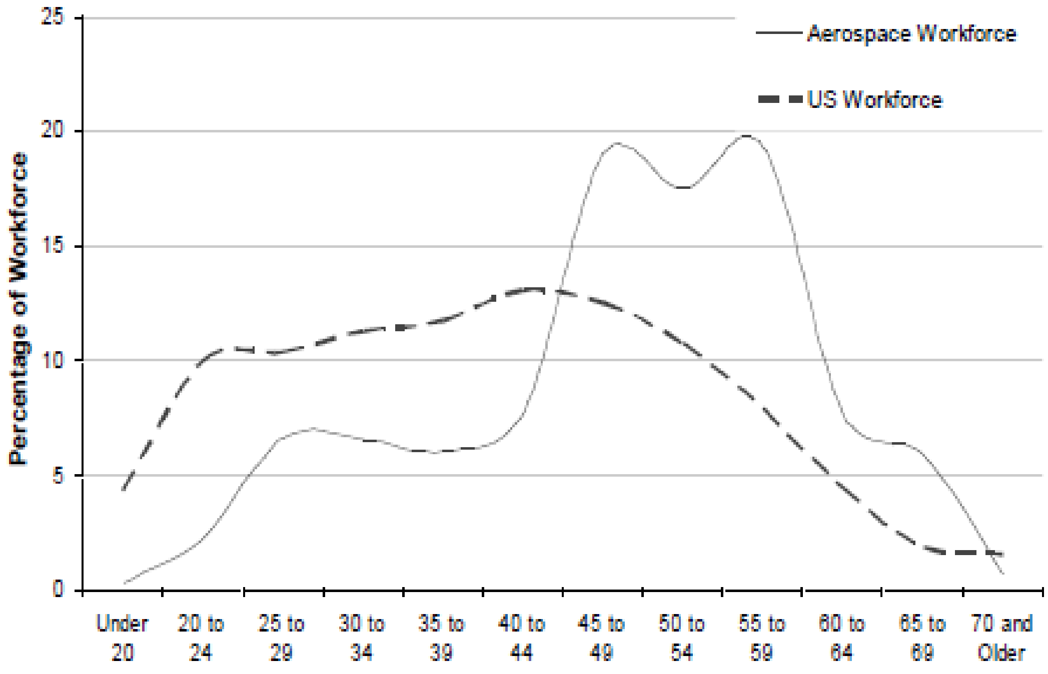


*Figure 2: Age distribution of the aerospace business workforce compared to the total U.S. workforce*[1]

**Knowledge retention will play a critical role in the future of satellite propulsion**

# Work Force Short Fall

- **There is the potential in the next 10 years for ~42,600 positions to go unfilled (183,214-140,598=42,616)**
  - **Loss of aerospace and mechanical engineers to jobs outside engineering and science professions is ~38.6% (88,202)**
  - **Universities today are pushing their limits to produce earned engineering bachelors degrees (228,800-88,202 = 140,598)**

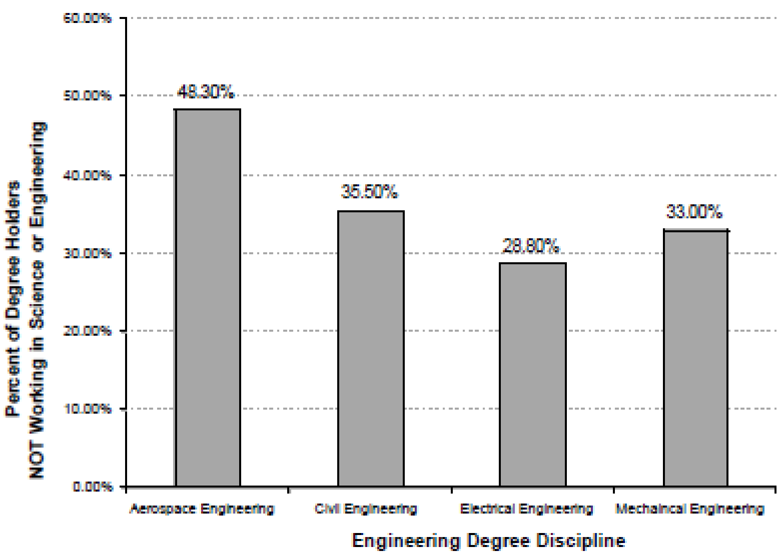


*Figure 3: Percent of engineers working outside the engineering and science professions*[1]

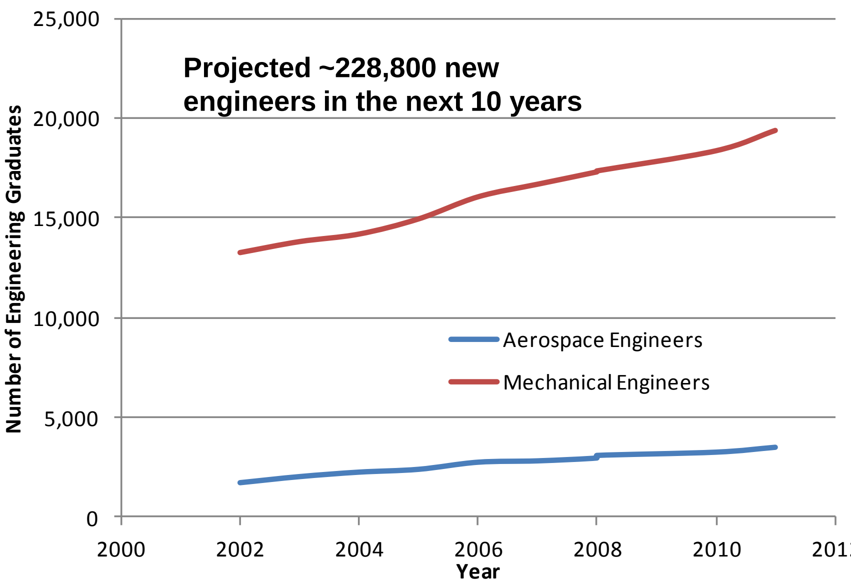


*Figure 4: Number of aerospace & mechanical engineers earning bachelor degrees*[2]

**Hiring, training and retaining people will be key requirement for the future of satellite propulsion**



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# Future Path Forward for Satellite Propulsion

- **Euro consult's estimates 1,145 satellites will be built for launch between 2011 to 2020**
  - **51% more satellites than the previous decade[4]**
- **Propulsion subsystems remain a satellite enabler**
  - **Flexibility**
    - **Subsystem/component simplification**
    - **Improvements in reliability**
  - **Higher performance**
    - **Increase in efficiencies or improved capabilities needed for mature technologies**
  - **Cost**
    - **Continued reductions in non-recurring and recurring costs must continue**
    - **Continued use of previously qualified hardware where possible**
  - **People**
    - **Maintaining a skilled engineering work force in the future will be key**

**The future of satellite propulsion is bright but not without challenge**



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# Presentation References

- **References:**
- **1) From Garth Henning and Richard Leshner, NASA, presentation to the Committee on Meeting the Workforce Needs for the National Vision for Space**
- **2) Engineering by the numbers: By Brian L. Yoder, PHD**
- **3) Satellite Electric Propulsion: Key Questions for Satellite Operators and their suppliers: By Greg Allen with Royce Dalby, Stephen Ganote and Tim Wickham**
- **4) Satellite Industry Growth to Continue Despite Challenging Environment: Space Daily Staff writers, Paris France Feb, 2012**

# 702 HP XIPS Performance

| Performance Parameter | Value | |
|---|---|---|
| | Low Power | High Power |
| Thrust | 79 mN | 165 mN |
| Specific impulse | 3,400 sec | 3,500 sec |
| Thruster power | 2.0 kW | 4.2 kW |
| Total power consumption | 2.2 kW | 4.5 kW |
| Xenon capacity | 266 kg | |
| GXP travel range, each orthogonal axis | 66.7º | |
| Total subsystem dry mass | 150 kg | |



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# Typical 702 HP XIPS System