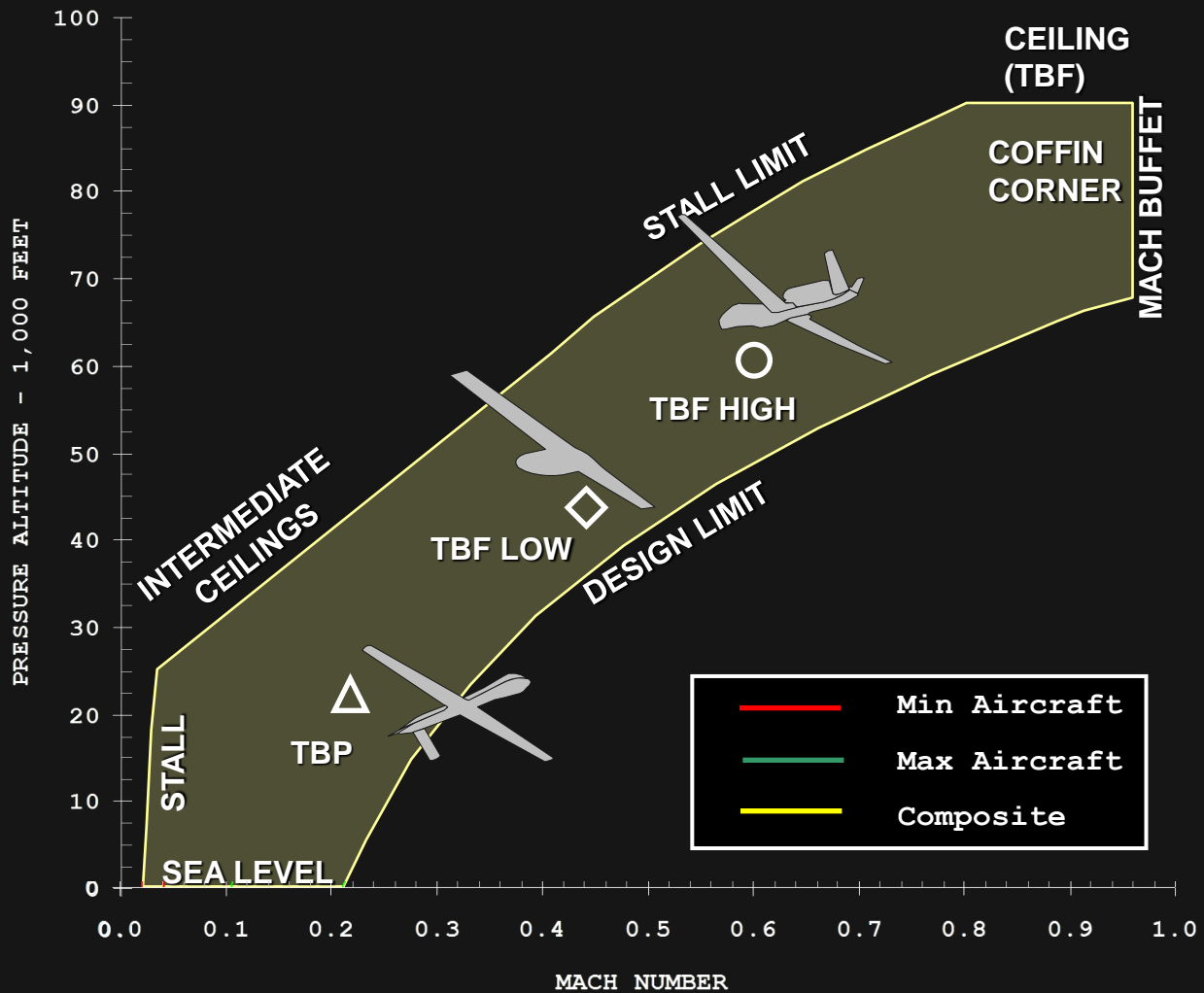


## MALE/HALE Trade Study Air Vehicle Capabilities



# Composite Flight Envelope



## Assumptions

- **Max Parameters**
  - *Lift Coefficient = 2.5*
  - *Wing Area = 1,000 ft<sup>2</sup>*
  - *Altitude = 90 kft (Turbine)*
  - *Load Factor = 4.0*
  - *Mach Number = 0.95 (Buffet)*
- **Min Parameters**
  - *Wing Area = 10 ft<sup>2</sup>*
  - *Altitude = 25 kft (Piston)*
- **Standard Day Atmosphere**
- **Linear Interpolation/Fairing Between Envelopes**



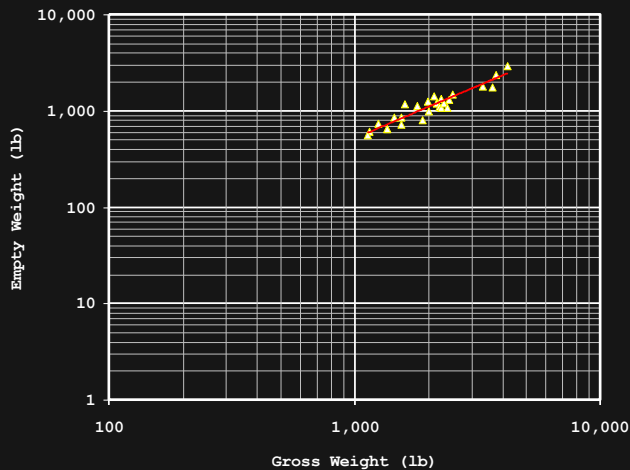
# Sizing & Matrix

Classification	$W_0$	$W_{pay}$	TOS	Radius	BCM	BCA
Units	lb	lb	hr	nm	mach	ft MSL
<b>Turboprop</b>	9,000	500	12	400	0.20	20,000
<b>Turbofan Low</b>	9,000	1,200	18	1,000	0.38	40,000
<b>Turbofan High</b>	32,000	3,000	24	2,000	0.66	50,000

Gross vs. Empty

$$y = 0.2945x^{1.0819}$$

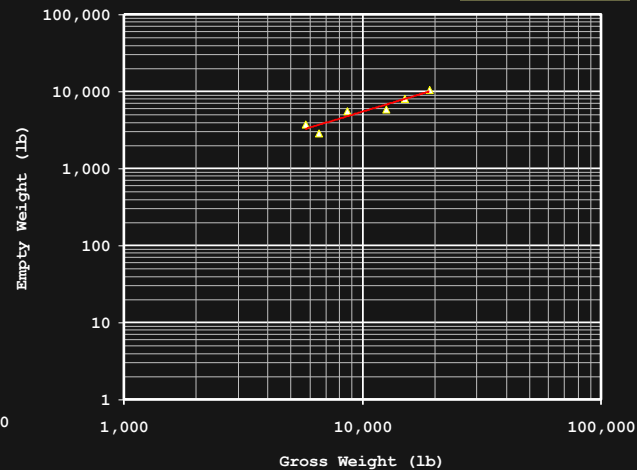
$$R^2 = 0.8901$$



Gross vs. Empty

$$y = 0.9708x^{0.9371}$$

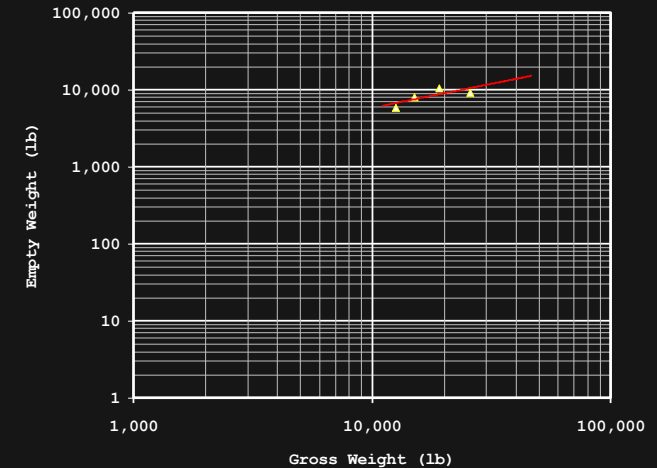
$$R^2 = 0.885$$



Gross vs. Empty

$$y = 19.277x^{0.6201}$$

$$R^2 = 0.6084$$

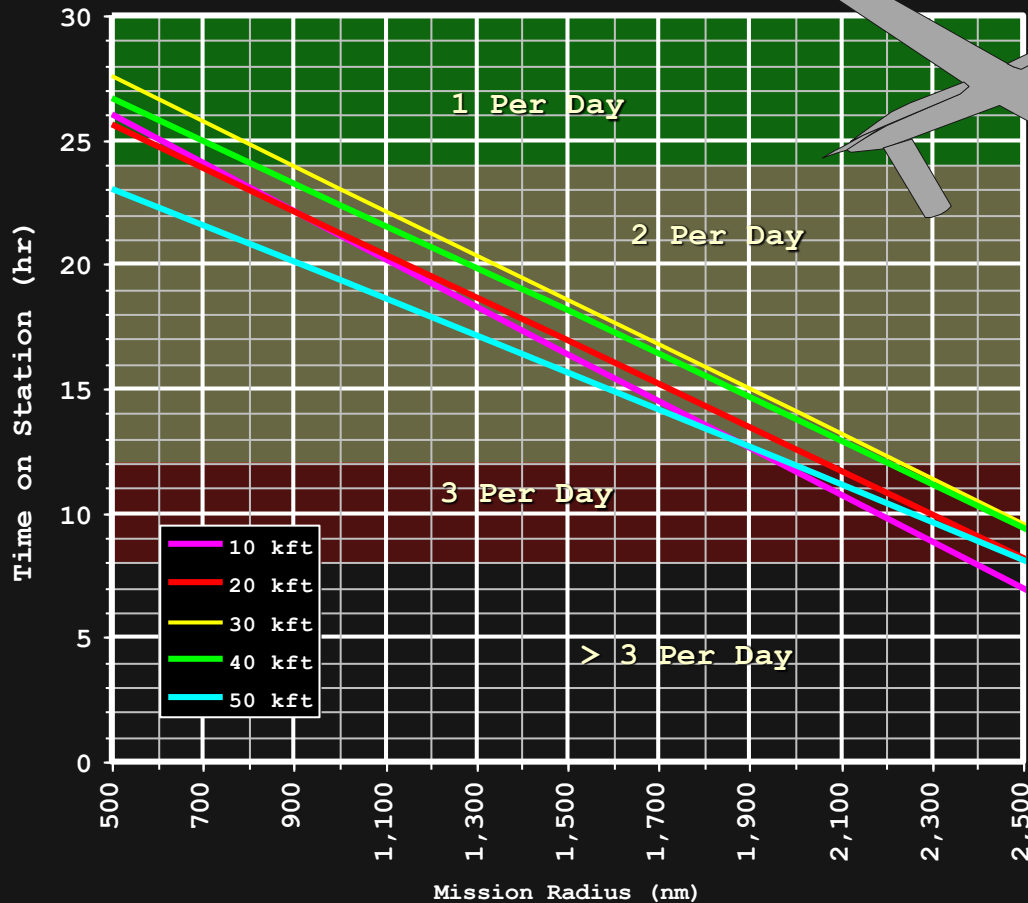




# Performance - Turboprop

## Radius vs. Time on Station

Optimum Transit Speed  
Optimum Altitude Rate Changes



## Assumptions

- Airframe
  - $CD_0 = 0.0259$
  - Max Lift Coef. = 2.0
  - Wing Area = 303 ft<sup>2</sup>
  - Max Load Factor = 3.8
- Propulsion
  - $SFC_0 = 0.56$  lbm/hr-hp
  - Max Thrust<sub>0</sub> = 1,700 lb
- Weight
  - Payload = 1,150 lb
  - Empty = 4,554 lb
  - Fuel = 5,296 lb (250 lb unusable)
  - Gross = 11,000 lb
- Power Draw
  - Accessories = 5 kW
  - Payload = 45 kW (on station)

Fuel per Time on Station for 1,000 nm Radius @ 20kft = 250 lb/hr



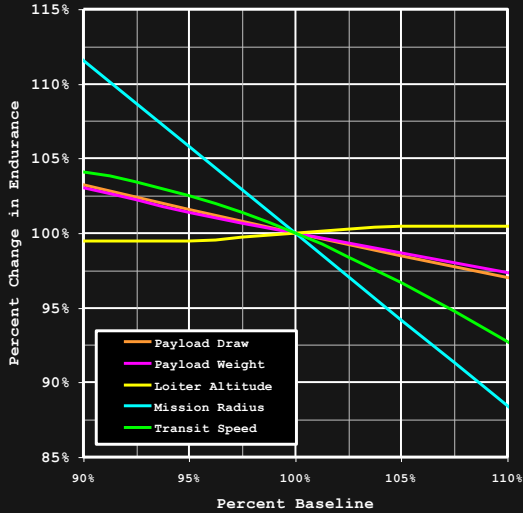
# Sensitivity Study – Turboprop 170 ktas Cruise

Time on Station Sensitivity

10,000 ft MSL

1,000 nm Radius

9.73 hr Endurance Baseline

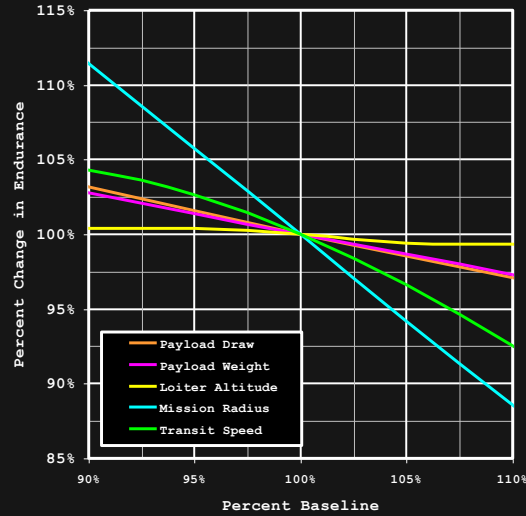


Time on Station Sensitivity

20,000 ft MSL

1,000 nm Radius

9.86 hr Endurance Baseline

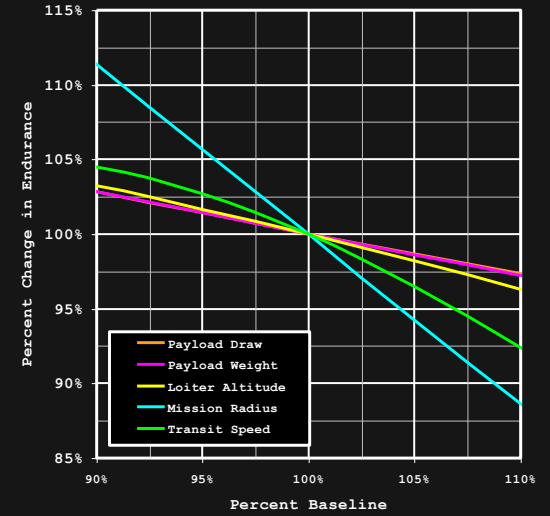


Time on Station Sensitivity

30,000 ft MSL

1,000 nm Radius

9.20 hr Endurance Baseline

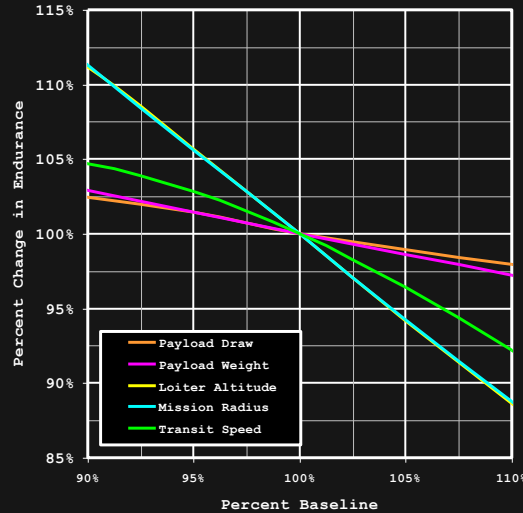


Time on Station Sensitivity

40,000 ft MSL

1,000 nm Radius

7.61 hr Endurance Baseline

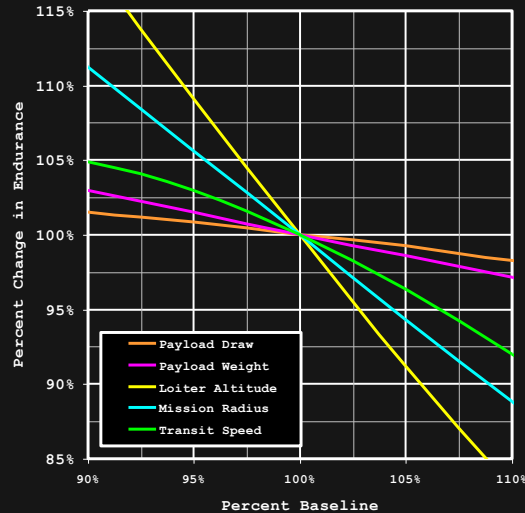


Time on Station Sensitivity

50,000 ft MSL

1,000 nm Radius

5.50 hr Endurance Baseline

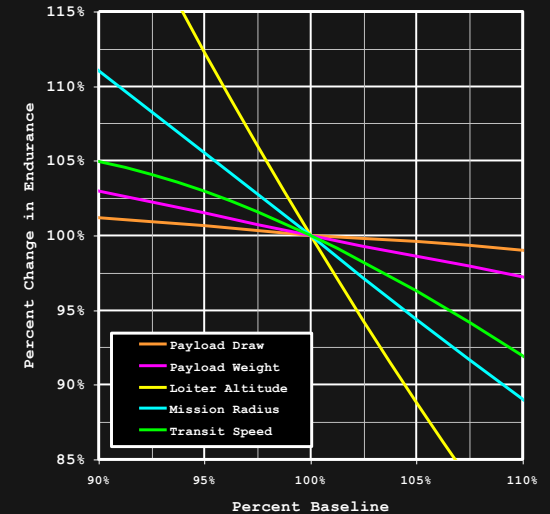


Time on Station Sensitivity

60,000 ft MSL

1,000 nm Radius

3.77 hr Endurance Baseline

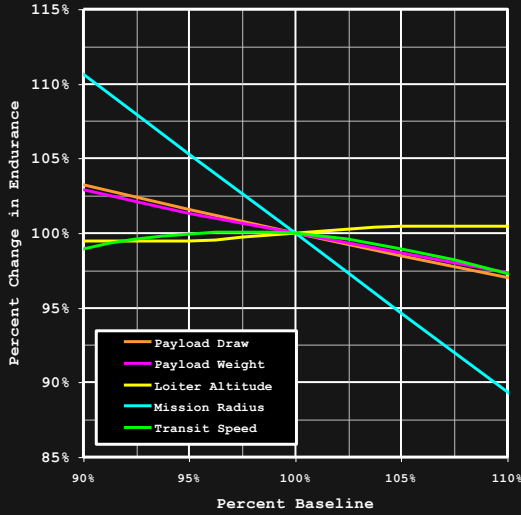




# Sensitivity Study – Turboprop Optimum Cruise

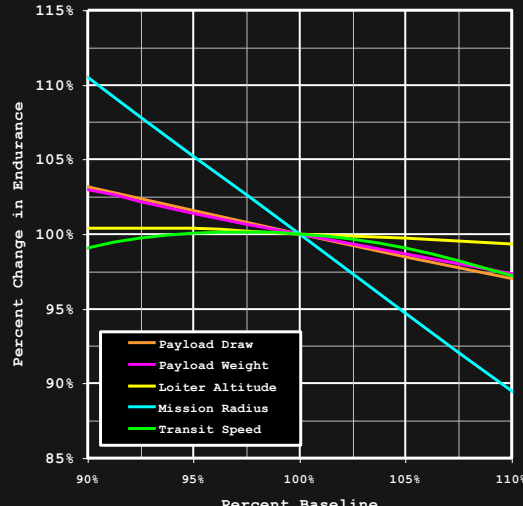
Time on Station Sensitivity

10,000 ft MSL  
1,000 nm Radius  
150 ktas Transit Speed  
10.16 hr Endurance Baseline



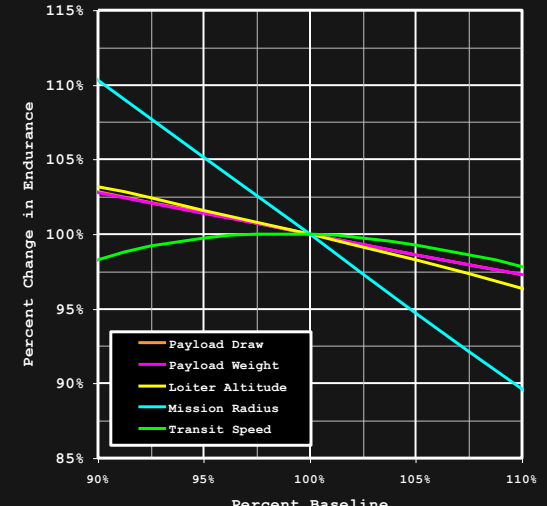
Time on Station Sensitivity

20,000 ft MSL  
1,000 nm Radius  
150 ktas Transit Speed  
10.32 hr Endurance Baseline



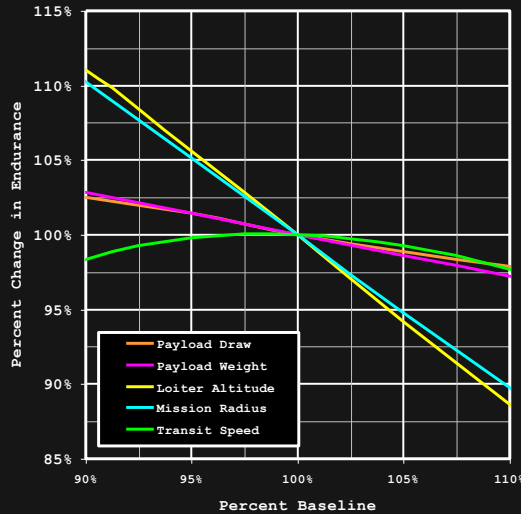
Time on Station Sensitivity

30,000 ft MSL  
1,000 nm Radius  
147 ktas Transit Speed  
9.66 hr Endurance Baseline



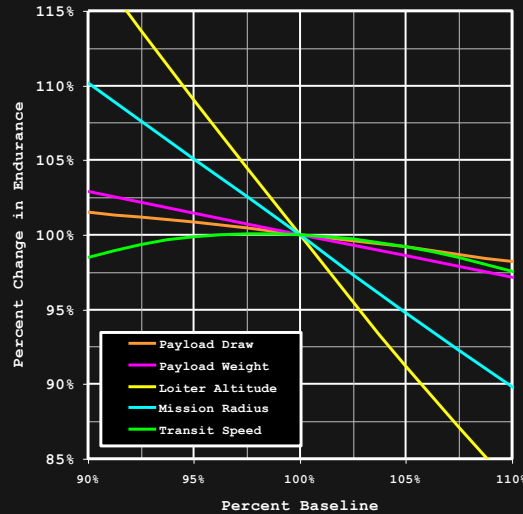
Time on Station Sensitivity

40,000 ft MSL  
1,000 nm Radius  
147 ktas Transit Speed  
8.01 hr Endurance Baseline



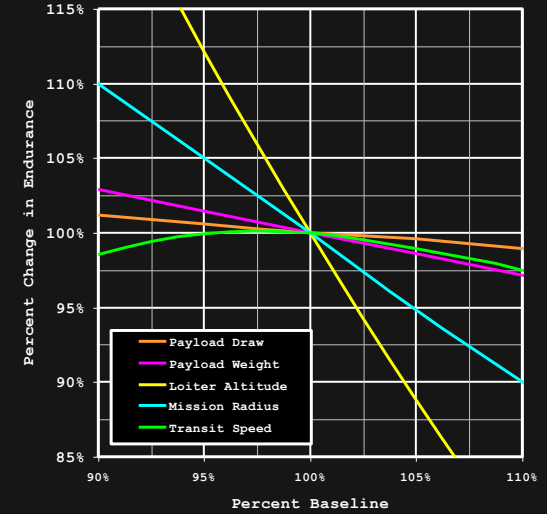
Time on Station Sensitivity

50,000 ft MSL  
1,000 nm Radius  
147 ktas Transit Speed  
5.80 hr Endurance Baseline



Time on Station Sensitivity

60,000 ft MSL  
1,000 nm Radius  
147 ktas Transit Speed  
3.98 hr Endurance Baseline



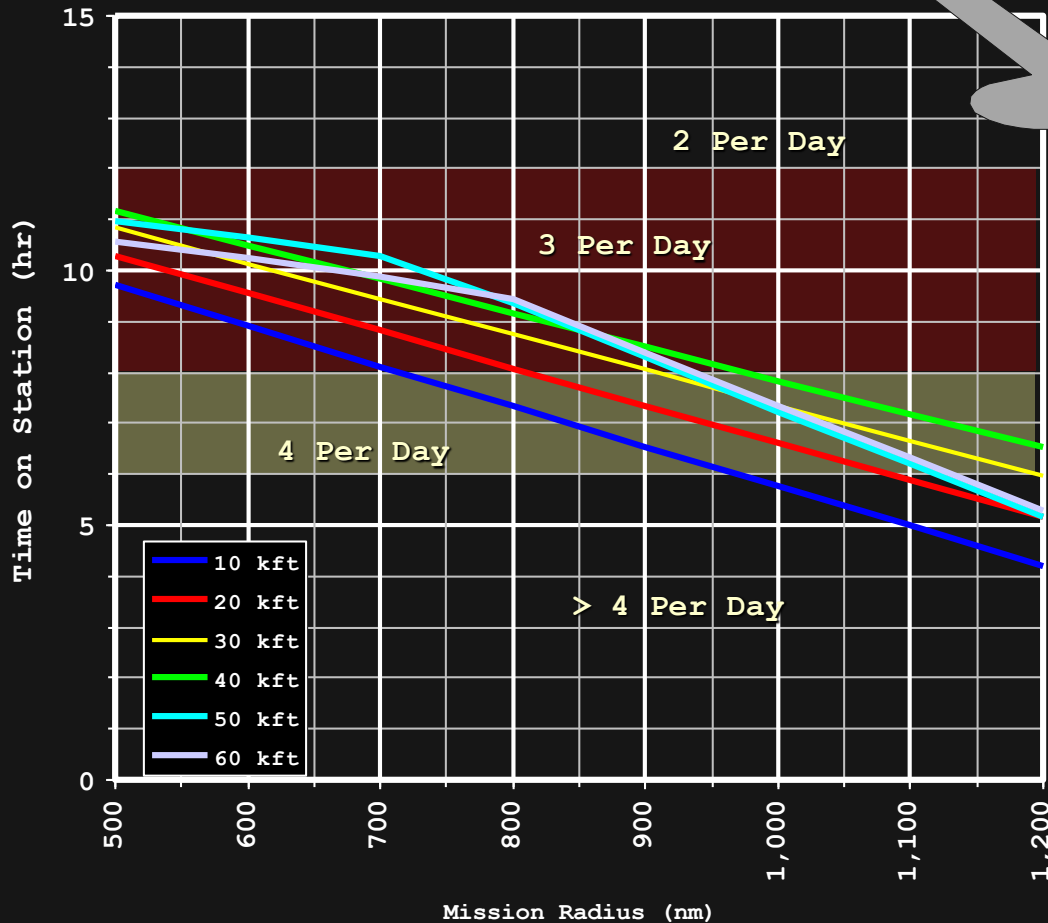


# Performance - Turboprop

## Radius vs. Time on Station

Optimum Transit Speed

Optimum Altitude Rate Changes



## Assumptions

### • Airframe

- $CD_0 = 0.0190$
- Max Lift Coef. = 0.65
- Wing Area = 320 ft<sup>2</sup>
- Max Load Factor = 3.8

### • Propulsion

- $TSFC_0 = 0.48 \text{ lbm/hr-lb}$
- Max Thrust<sub>0</sub> = 1,900 lb

### • Weight

- Payload = 400 lb
- Empty = 4,600 lb
- Fuel = 3,600 lb (250 lb unusable)
- Gross = 8,600 lb

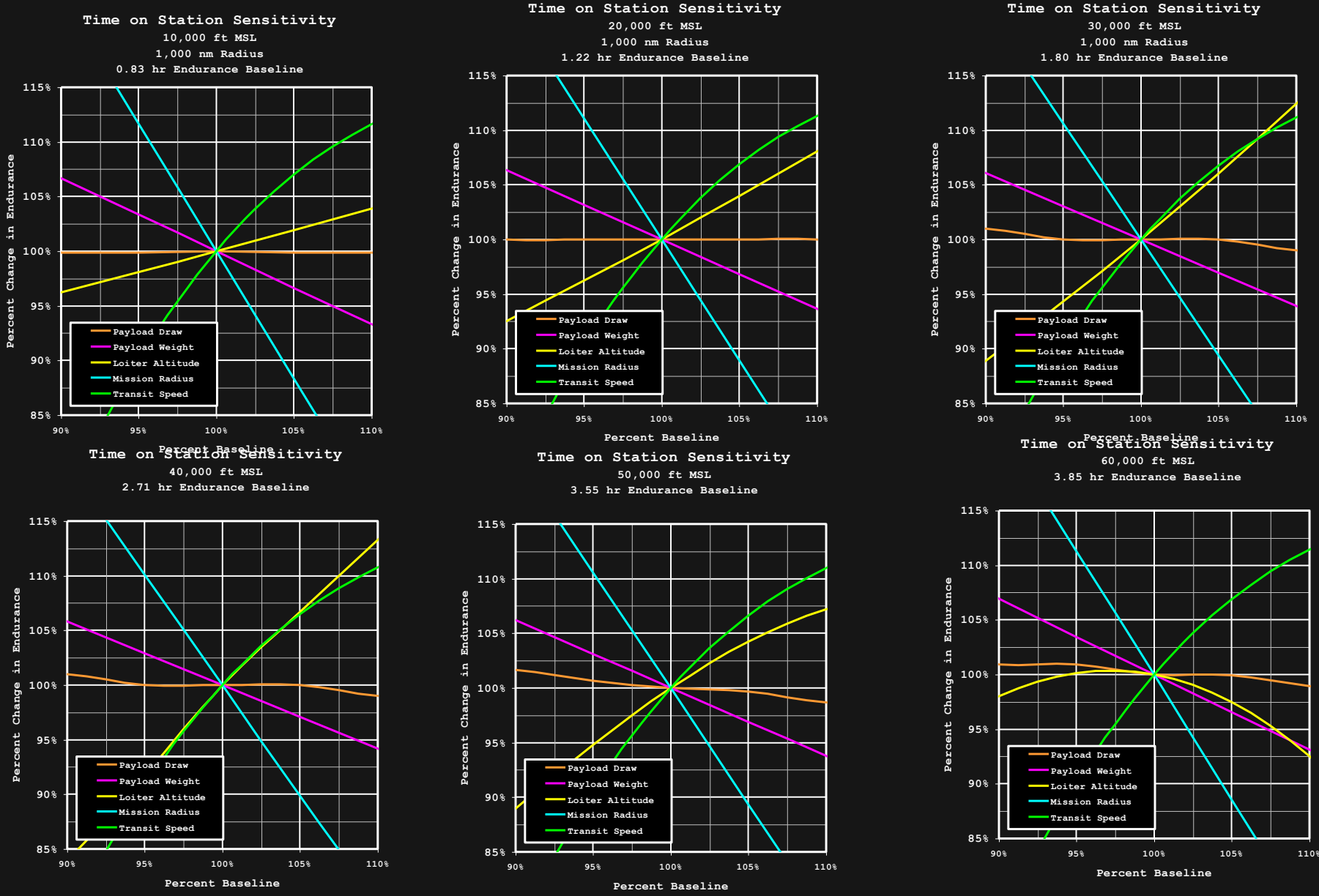
### • Power Draw

- Accessories = 5 kW
- Payload = 45 kW (on station)

Fuel per Time on Station for 1,000 nm Radius @ 10kft = 626 lb/hr



# Sensitivity Study – TBF Low 170 ktas Cruise







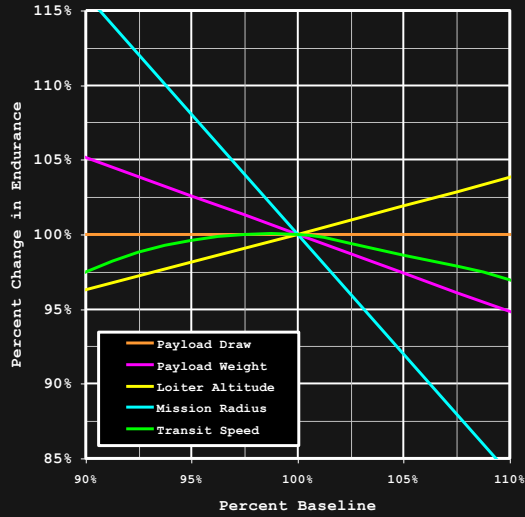
# Sensitivity Study – TBF Low Optimum Cruise

Time on Station Sensitivity

10,000 ft MSL

230 ktas Transit Speed

1.04 hr Endurance Baseline

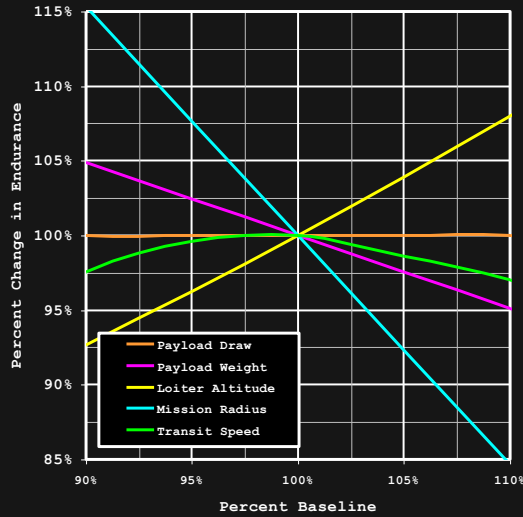


Time on Station Sensitivity

20,000 ft MSL

230 ktas Transit Speed

1.51 hr Endurance Baseline

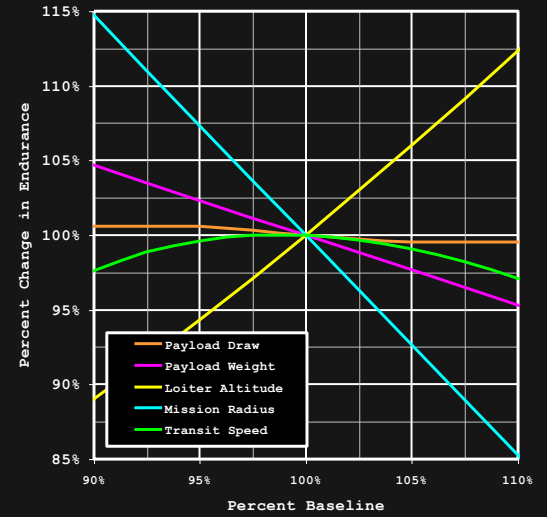


Time on Station Sensitivity

30,000 ft MSL

230 ktas Transit Speed

2.23 hr Endurance Baseline

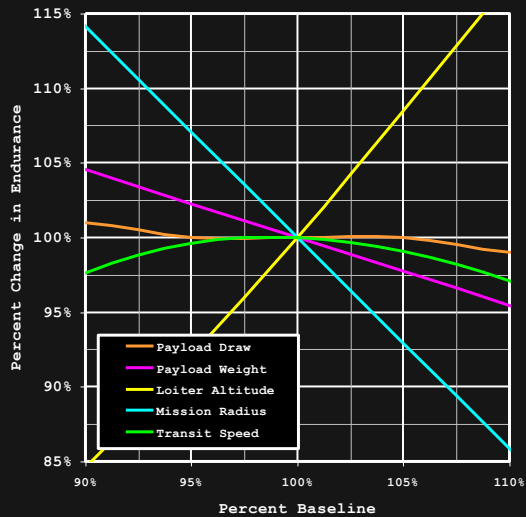


Time on Station Sensitivity

40,000 ft MSL

230 ktas Transit Speed

3.23 hr Endurance Baseline

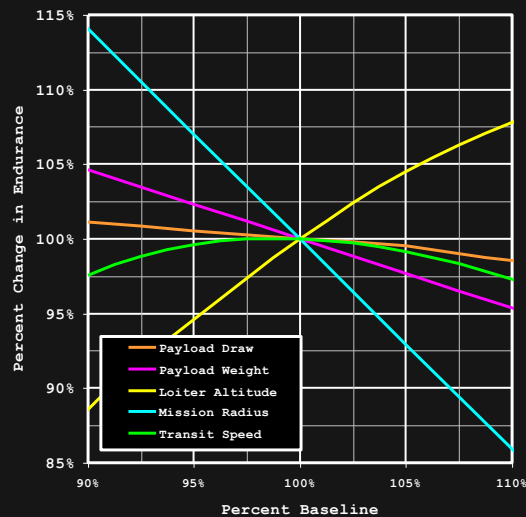


Time on Station Sensitivity

50,000 ft MSL

230 ktas Transit Speed

4.56 hr Endurance Baseline

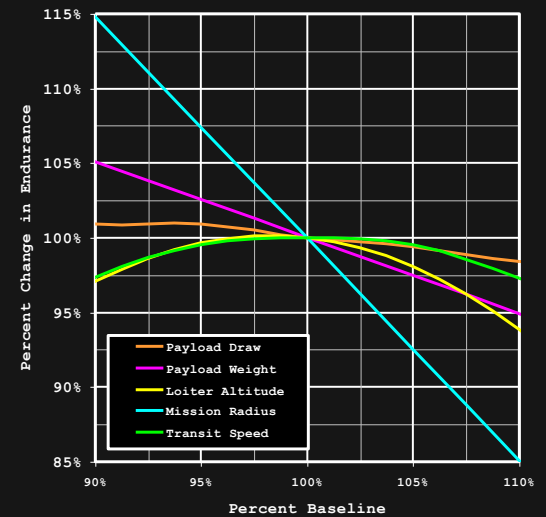


Time on Station Sensitivity

60,000 ft MSL

230 ktas Transit Speed

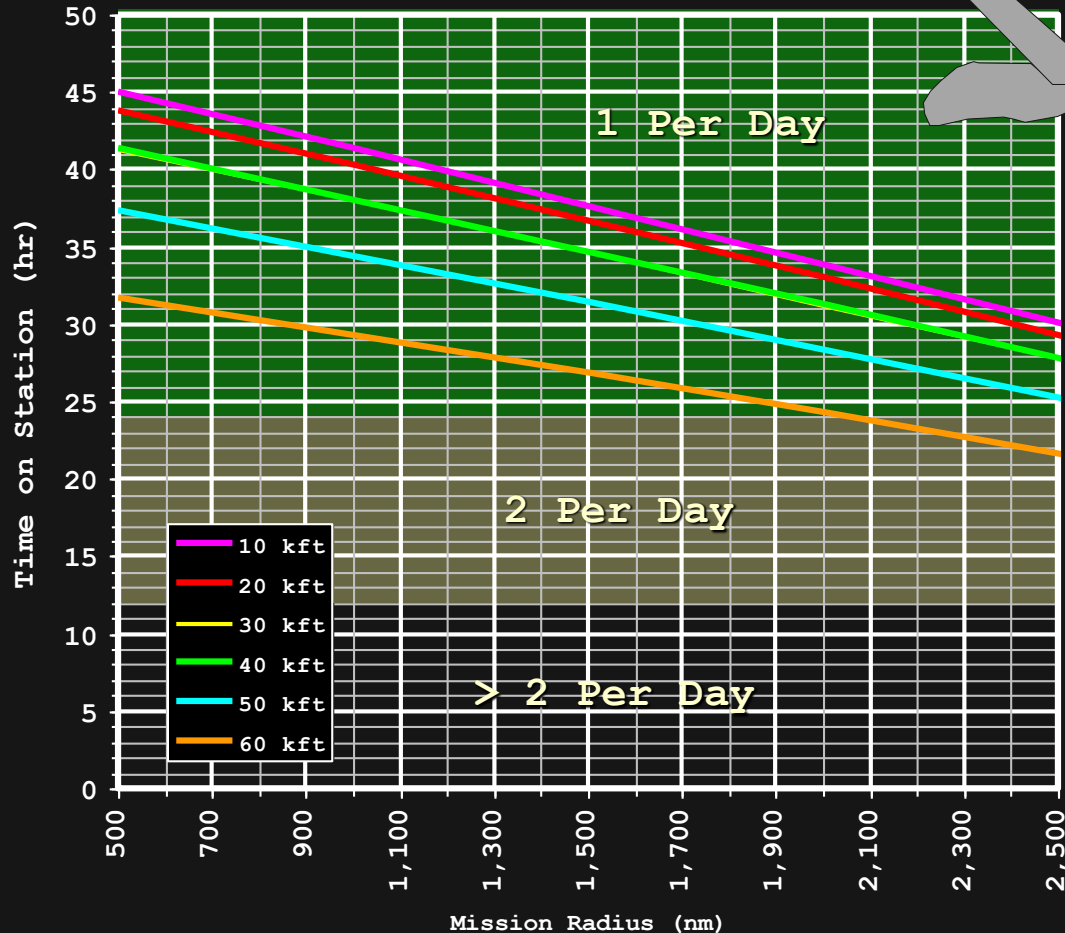
5.01 hr Endurance Baseline



# Performance – Turbofan High

## Radius vs. Time on Station

Optimum Transit Speed  
Optimum Altitude Rate Changes



## Assumptions

### • Airframe

- $CD_0 = 0.0120$
- Max Lift Coef. = 2.0
- Wing Area = 685 ft<sup>2</sup>
- Max Load Factor = 3.8

### • Propulsion

- $TSFC_0 = 0.33$  lbm/hr-lb
- Max Thrust<sub>0</sub> = 8,300 lb

### • Weight

- Payload = 1,150 lb
- Empty = 11,670 lb
- Fuel = 19,430 lb (777 lb unusable)
- Gross = 32,250 lb

### • Power Draw

- Accessories = 5 kW
- Payload = 45 kW (on station)

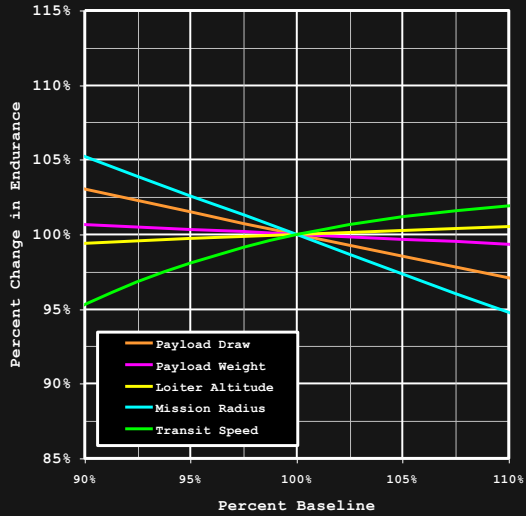
Fuel per Time on Station for 1,000 nm Radius @ 20kft = 485 lb/hr



# Sensitivity Study – TBF High – 170 ktas Cruise

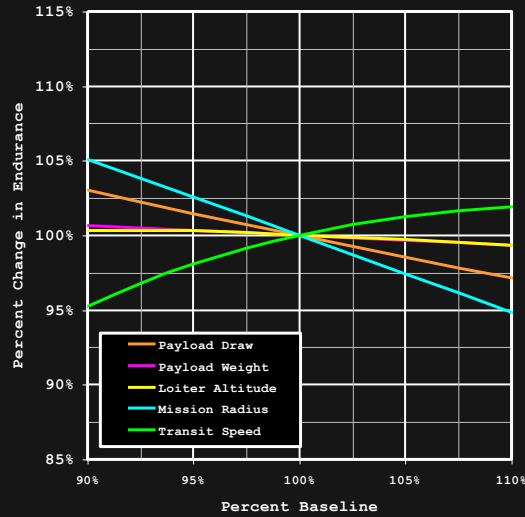
**Time on Station Sensitivity**

10,000 ft MSL  
1,000 nm Radius  
170 ktas Transit Speed  
15.91 hr Endurance Baseline



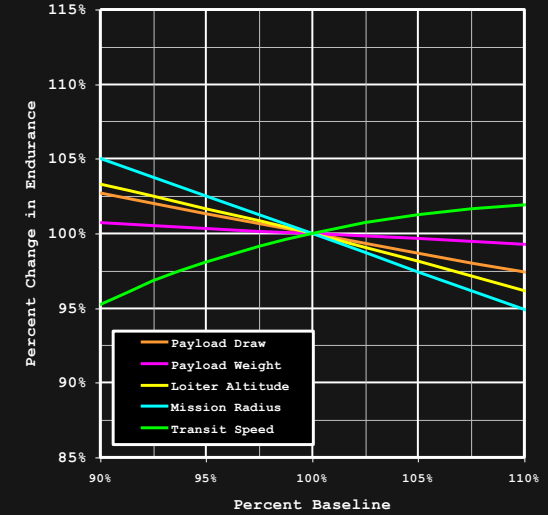
**Time on Station Sensitivity**

20,000 ft MSL  
1,000 nm Radius  
170 ktas Transit Speed  
16.20 hr Endurance Baseline



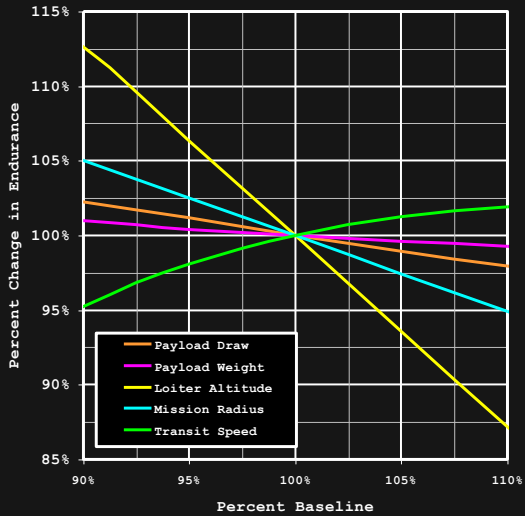
**Time on Station Sensitivity**

30,000 ft MSL  
1,000 nm Radius  
170 ktas Transit Speed  
15.11 hr Endurance Baseline



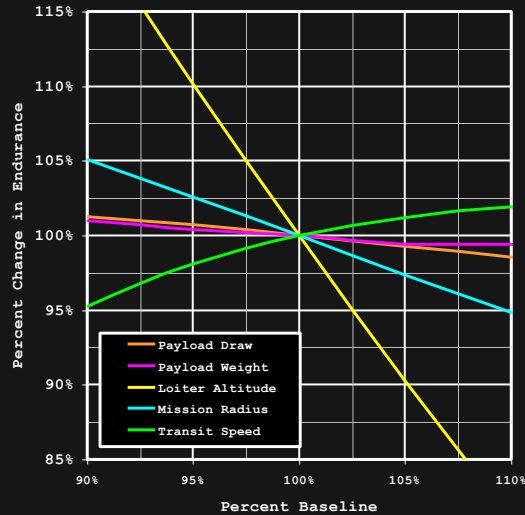
**Time on Station Sensitivity**

40,000 ft MSL  
1,000 nm Radius  
170 ktas Transit Speed  
12.28 hr Endurance Baseline



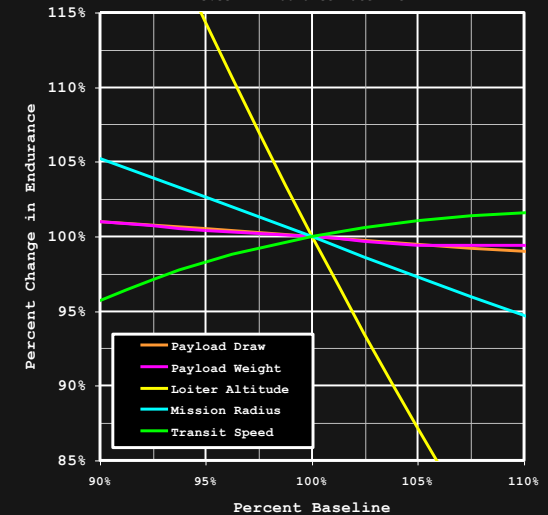
**Time on Station Sensitivity**

50,000 ft MSL  
1,000 nm Radius  
170 ktas Transit Speed  
8.52 hr Endurance Baseline



**Time on Station Sensitivity**

60,000 ft MSL  
1,000 nm Radius  
170 ktas Transit Speed  
5.55 hr Endurance Baseline

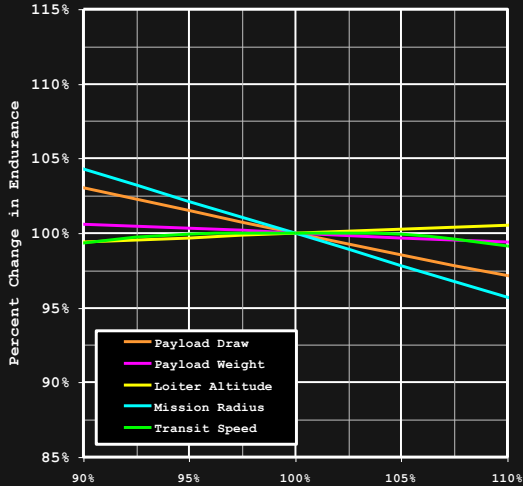




# Sensitivity Study – TBF High Optimum Cruise

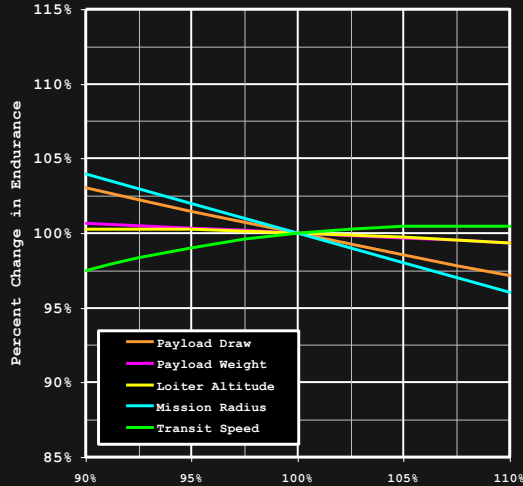
Time on Station Sensitivity

10,000 ft MSL  
1,000 nm Radius  
225 ktas Transit Speed  
16.61 hr Endurance Baseline



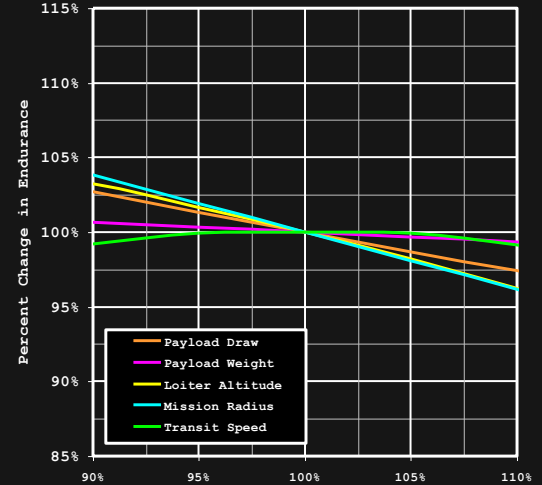
Time on Station Sensitivity

20,000 ft MSL  
1,000 nm Radius  
225 ktas Transit Speed  
17.03 hr Endurance Baseline



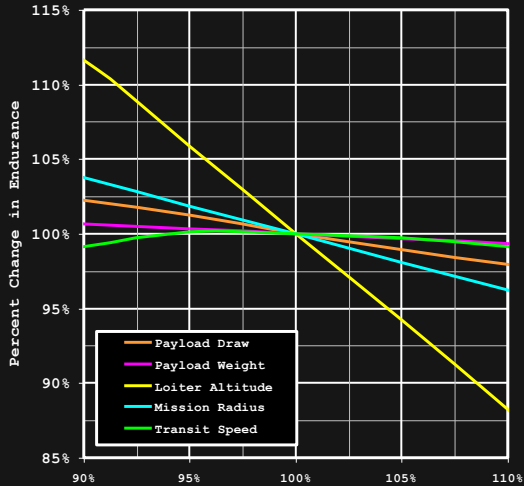
Time on Station Sensitivity

30,000 ft MSL  
1,000 nm Radius  
250 ktas Transit Speed  
16.00 hr Endurance Baseline



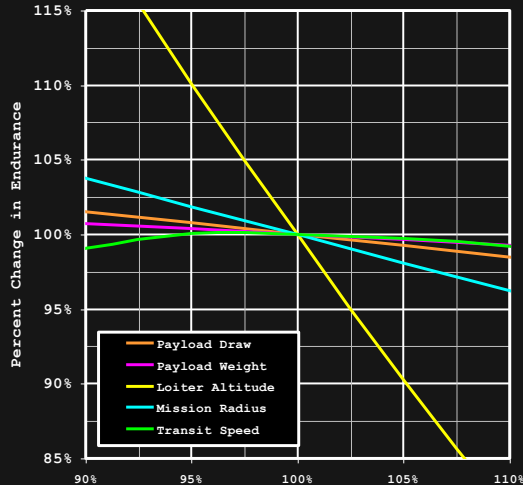
Time on Station Sensitivity

30,000 ft MSL  
1,000 nm Radius  
250 ktas Transit Speed  
13.16 hr Endurance Baseline



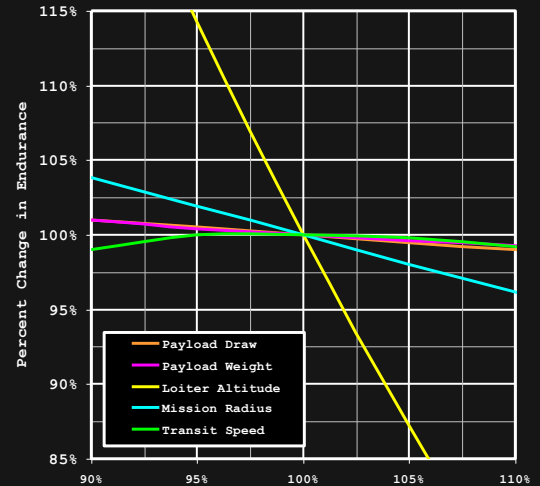
Time on Station Sensitivity

50,000 ft MSL  
1,000 nm Radius  
250 ktas Transit Speed  
9.30 hr Endurance Baseline



Time on Station Sensitivity

60,000 ft MSL  
1,000 nm Radius  
250 ktas Transit Speed  
6.05 hr Endurance Baseline







# Air Vehicle Design Space

TIME ON STATION [HR]



TRANSIT SPEED [MACH NUMBER]

TBP

ALTITUDE DELTA [KFT]



TRANSIT SPEED [MACH NUMBER]

ALTITUDE DELTA [KFT]

TBF LOW



TRANSIT SPEED [MACH NUMBER]

ALTITUDE DELTA [KFT]

TBF HIGH

**CONSTRAINTS**

- PAYLOAD WEIGHT LIMIT
- RADIUS LIMIT

