MISSION OPERATIONS DIRECTORATE
FLIGHT DIRECTOR OFFICE

ENTRY OPTIONS TIGER TEAM

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ENTRY OPTIONS
Agenda/Contents

- Previous Results - Summarized
- STS-107 Weight Reduction Scenarios
- Results - Summarized
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- Weight Reduction Combinations - Scenarios 1,2, & 3
- Cold Soak Results - Summarized
- Conclusions

ENTRY OPTIONS
Previous Results - Summary

- Best case sensitivity study using certified deorbit targeting and STS-107 trajectory initial conditions to evaluate wing leading edge (WLE) and two body points, one forward and one aft of MLG door. (see Backup Chart 1 for diagram)
  - Control parameters: altitude, weight, c.g., crossrange, N-cycles (trajectory steepness), approach (ascending/descending), hemisphere (atmosphere), and prebank.
- Results were as follows:
  - No significant thermal relief for **any single control variable.**
  - Best case **control variable combinations:**
    - WLE body point 5505 (RCC): ~ 5% reduction in WLE max. temp.
    - Body point 1602 (tile): ~ 20% reduction for heat load, ~ 30% reduction for heat rate.
    - Body point 2360 (tile): ~ 20% reduction for heat load, ~ 40% reduction for heat rate.
- Caveats to results:
  - All results were for a "no damage" scenario. For damage, the heat load and heat rate reductions would likely not be directly applicable, depending on the degree of damage.
  - Best case combinations were not proven to be achievable.
- Analysis results verified our previous understanding: Using certified deorbit targeting methods, the only way to reduce the STS-107 heating profile would be to <u>significantly</u> reduce the weight (while maintaining acceptable c.g.) and to lower the orbit altitude prior to deorbit.

ENTRY OPTIONS
STS-107 Weight Reduction Scenarios

- OVE WG (3/17/03) and PRCB (3/13/03) direction was to finalize the best case analyses for STS-107 initial conditions, and to not pursue development of any uncertified or contingency deorbit/entry profiles at this time.
- The team developed three different weight reduction scenarios for STS-107, and combined them with other best-on-best case conditions (altitude reduction, approach trajectory, etc.) as in previous analyses.
  - Best case weight reduction categories included consumables (ECLSS, APU, Cryo, Prop), deployable items (middeck, flight deck, crew equipment, avionics, Spacehab), and jettison items (Spacehab, FREESTAR/GAS cans, and radiator panels).
  - Categories of weight reduction were not verified achievable, either alone (e.g. consumables), or in combination with other categories.
    - For each of the weight reduction scenarios, we assumed we could do it all.
    - This may not be realistic for some of the scenarios – the goal was to find the upper bound on the weight reduction.
  - Deployable and jettison items were grouped into scenarios that were limited only by available EVA time (12 hours).
- The associated entry trajectories were simulated, the results of which were analyzed using the TSEP model.

ENTRY OPTIONS
Results - Summary

- Weight reduction scenario 3 (consumables, deployable items, Spacehab jettison, and FREESTAR jettison) yielded the best results, with a total weight reduction of 31,321 lbm.
- Using certified deorbit targeting and STS-107 trajectory initial conditions, and the best case combination of other control variables, scenario 3 yielded the following results:
  - WLE body point 5505 (RCC): ~ 7% reduction in WLE max. temp.
  - Body point 1602 (tile): ~ 24% reduction heat load, ~ 34% reduction heat rate.
  - Body point 2360 (tile): ~ 29% reduction heat load, ~ 56% reduction heat rate.
- Caveats to results:
  - Detailed risk assessment was not performed, however it is clear that the increase in risk would be very significant in order to achieve these weight reductions.
    - Numerous flight rule violations (e.g. consumables management, EVA, etc.).
    - Numerous undocumented/unverified procedures (e.g. EVA jettison tasks, IFM, etc.).
  - Combination of weight reduction categories (consumables, deployable items, and jettison) was not verified to be feasible (timeline, crew workload, detailed EVA task, etc.)
  - All results were for a “no damage” scenario. For damage, the heat load and heat rate reductions would likely not be directly applicable, depending on the degree of damage.
  - Best case combination of trajectory variables was not proven to be achievable.

ENTRY OPTIONS

Results – Summary (Cont'd)

- Weight reduction scenario 1 (consumables, deployable items, Spacehab deployable items, GAS cans, and radiator panels) yielded a total weight reduction of 20,387 lbm, the results of which were:
  - WLE body point 5505 (RCC): ~ 6% reduction in WLE max. temp.
  - Body point 1602 (tile): ~ 17% reduction heat load, ~ 33% reduction heat rate.
  - Body point 2360 (tile): ~ 23% reduction heat load, ~ 46% reduction heat rate.
- Weight reduction scenario 2 (consumables, deployable items, Spacehab deployable items, radiator panels, and FREESTAR jettison) yielded a total weight reduction of 22,924 lbm, the results of which were:
  - WLE body point 5505 (RCC): ~ 6% reduction in WLE max. temp.
  - Body point 1602 (tile): ~ 18% reduction heat load, ~ 33% reduction heat rate.
  - Body point 2360 (tile): ~ 23% reduction heat load, ~ 45% reduction heat rate.
- Caveats to results:
  - Same as for Scenario 3
- Trajectory/TSEP data included in backup charts.

ENTRY OPTIONS
Weight Reduction – Consumables

- Consumables (total reduction 4159 lbm)
  - ECLSS (total 650 lbm)
    - All supply water tanks other than tank A dumped to zero (393).
    - Waste tank to minimum (79).
    - Both ammonia (NH3) tanks depleted (92).
    - GN2 systems at minimums (86).
  - APU/HYD (total 560 lbm)
    - One APU run to depletion (278).
    - Other two APU's run to minimum quantities (222).
    - Cooling water (WSB) reduction due to APU run time (60).
  - Cryo H2/O2 (total 1600 lbm)
    - Tanks 3-9 (EDO and Orbiter) reduced to minimum residuals.
    - Remaining cryo vented overboard through relief valves.
      - Tank heaters used to over-pressurize tanks.
      - Excess cryo at the end of the mission could be "dumped" in less than one day.
    - Tanks 1 and 2 at minimums to support deorbit/entry.

ENTRY OPTIONS
Weight Reduction – Consumables (Cont'd)

- Consumables (cont'd)
  - PROP (total 1349 lbm)
    - FRCS dumped to zero – nominal ops.
    - ARCS reduced to minimum to support mean entry to 0.05g, at which point exactly 20% remains (1349).
  - Impacts include numerous flight rule violations and undocumented procedures.
    - Absolute minimums in critical systems.
    - No deorbit waveoff opportunities.
    - No postlanding capability (cooling or power).
    - Zero fault tolerance, or reduced fault tolerance.
- Itemized weight/c.g. details included in backup charts.

ENTRY OPTIONS
Weight Reduction – Deployable Items

- Deployable items (total reduction 16,228 lbm)
  - All loose items, and items that could be made loose (via IFM, for example) and deployed overboard via EVA.
- Items included from the following areas:
  - Middeck, flight deck, avionics bays (LRU’s), crew equipment (4663).
  - Spacehab module - systems, experiment payloads, racks (8017).
  - GAS cans (1891).
  - Radiator Panels (1657).
- Itemized weight/c.g. details included in backup charts.

ENTRY OPTIONS

Weight Reduction – Spacehab Jettison

- Perform EVA to disconnect Spacehab module and jettison from payload bay. (18,071 lbm)
  - Use EVA torque multiplier tool to open all four sill passive latches, and use EVA pins to restrain floating latches.
  - Disconnect 23 electrical and water lines running from Orbiter to Spacehab.
    - Use EVA cable cutters to physically disconnect lines.
    - Only one inhibit to remove power prior to cutting lines.
  - Disconnect Spacehab from tunnel adapter at the flexible joint.
    - Flexible joint material is Kevlar, cloth, and wiring.
    - May have been able to use EVA and IFM tools to cut through joint.
  - Two potential options for getting Spacehab out of payload bay:
    - EVA crew (two) pull Spacehab out of the closed keel latch and open sill latches to gain clearance for Orbiter backaway.
    - Perform slow Orbiter backaway while Spacehab is in open sill latches and closed keel latch.
  - Impacts and Unknowns
    - No experience base to determine feasibility of either option.
    - EVA crew pull SH out of the keel latch – unknown forces. No foot restraints available, so task would be free floating.
    - Dynamics of separation from closed keel latch has not been analyzed.

ENTRY OPTIONS
Weight Reduction – FREESTAR Jettison

- Perform EVA to disconnect FREESTAR and jettison from payload bay. (4428 lbm)
  - Use EVA torque multiplier tool to open all four sill passive latches, and use EVA pins to restrain floating latches.
  - 8 electrical lines running from Orbiter to FREESTAR.
    - Use EVA cable cutters to physically disconnect lines.
    - Only one inhibit to remove power prior to cutting lines.
  - Impacts and Unknowns
    - Same options and concerns as Spacehab for getting FREESTAR out of payload bay.
      - Probably more feasible than SH jettison, from a mass handling perspective.
    - STS-107 only had two EVA latch pins manifested.
      - If both SH and FREESTAR were jettisoned, would need alternate means for restraining 2 floating passive latches.

ENTRY OPTIONS

FREESTAR/Spacehab Jettison and Separation

- Assume that EVA crew will completely detach FREESTAR (or Spacehab) and provide a clear path up out of the payload bay.
- Separation technique:
  - Orbiter performs small +Z body translation in free drift to slowly back away from FREESTAR (or Spacehab).
  - When FREESTAR (or Spacehab) clears the Orbiter mold line, the Orbiter will return to attitude hold and execute a standard separation sequence.
    - Separation Maneuver (1/2/3 Separation) Orbit Ops Checklist.
    - Provides a safe separation for any attitude.
  - Impacts and Unknowns
    - Small risk assuming the payload to be jettisoned is completely detached and cannot hang up as it exits the payload bay.
    - Separation techniques and procedures are published and well understood.

ENTRY OPTIONS

Weight Reduction Combinations – Scenarios 1 thru 3

- Table includes weight reduction categories used to develop combination scenarios.

Item	Description	Weight Reduction
A	Consumables	4159
B	Deployable Items (Middeck, Flight Deck, Avionics, Crew Equip.)	4663
C	Deployable from Spacehab (1)	8017
D	GAS Cans (2)	1891
E	Radiator Panels	1657
F	FREESTAR Jettison	4428
G	Spacehab Jettison	18071

(1) – Item C is a subset of the total weight from item G.

(2) – Item D is a subset of the total weight from item F.

ENTRY OPTIONS

Weight Reduction Combinations – Scenarios 1 thru 3 (Cont'd)

- Three scenarios were developed from logical combinations of the items listed in the table.
  - Scenario 1: Total weight reduction = 20,387 lbm
    - Weight/c.g. changes resulting from combination of items A thru E.
    - Includes consumables, deployable items, SH deployable items, GAS cans, and radiator panels.
    - Assumes risks associated with jettison of Spacehab or FREESTAR are too great, or jettison unsuccessful (e.g. cannot physically detach).
  - Scenario 2: Total weight reduction = 22,924 lbm
    - Weight/c.g. changes resulting from combination of items A, B, C, E & F.
    - Includes consumables, deployable items, SH deployable items, radiator panels, and FREESTAR jettison.
    - Assumes risks associated with jettison of Spacehab are too great, or jettison unsuccessful (e.g. cannot physically detach).

ENTRY OPTIONS

Weight Reduction Combinations – Scenarios 1 thru 3 (Cont'd)

- Scenario 3: Total weight reduction = 31,321 lbm
  - Weight/c.g. changes resulting from combination of items A, B, F &G.
  - Includes consumables, deployable items, FREESTAR jettison, and Spacehab jettison.
    - Radiator panel jettison was not included, because it was assumed that the EVA time required to perform both FREESTAR and SH jettison, as well as to deploy all other "deployables" would not leave time to also execute radiator jettison.
  - Assumes FREESTAR and Spacehab EVA jettison techniques can be developed and executed.

- Itemized weight/c.g. details for all three scenarios included in backup charts.

ENTRY OPTIONS
Weight Reduction Combinations – Scenarios 1 thru 3 (Cont'd)

- General Overriding Assumptions
  - Decision to perform weight reduction occurs early enough in the mission to develop the required plans and techniques.
    - Consumables – usage, overboard dumps, depletion burns, etc.
    - Deployable Items - required IFM's, "deploy packaging", etc.
    - Deployable Items - required EVA's, Orbiter maneuvers.
    - Jettison Items - required EVA's for detaching, jettisoning, cleanup of payload bay, etc.
  - Excessive risks associated with any of the three options (Scenario 1,2, or 3, or any other combination) would require that significant, and convincing data exists proving that the Orbiter could not survive entry.
  - Any and all possible weight reduction might be considered, depending on degree of concern, and time available.

ENTRY OPTIONS
Results - On-Orbit Coldsoak Post-Flight Analysis

- The STS-107 EOM attitude timeline did provide cold wings for entry.
  - Actual EI temps were 6 deg F and 3 deg F on lower and upper surfaces, respectively (temp. limit is 92 deg at EI).
- Best case left wing cold soak protecting all STS-107 thermal constraints (MLG tires, PLBD BET, structure, wave-off days), ECLSS, pointing and payloads yielded a 10 deg reduction in the left wing temp at EI.
- Best case, protecting only a single deorbit opportunity, cold soaking for 2 days, yielded a 50 deg reduction in left wing temp at EI.
- Best case, maximum possible cold soak (2+ days) and not protecting any other constraints yielded a 65 deg reduction in left wing temp at EI.
  - Reductions limited by low beta angle on STS-107.
- These EI wing temperature reductions are not significant.
  - On STS-107, wing temps may have increased as much as 700 deg in 400 seconds (1.75 deg/sec) post EI.
  - A 65 deg decrease in EI wing temp would have resulted in ~37 second delay in onset of same max. temps and heat load.

ENTRY OPTIONS
Conclusions

- Using certified deorbit/entry targeting:
  - WLE: No appreciable temperature reduction, even when considering extreme Orbiter weight reductions (Scenario 3).
  - Body points (Tile): Some heat rate and heat load reduction is possible with moderate-to-extreme Orbiter weight reductions (Scenarios 1 thru 3).
    - For damage scenarios, the reductions would likely not be directly applicable, depending on the degree of damage.
- In the final analysis, must balance heat rate and heat load for all body points.
  - Variations of the individual sensitivity parameters do not yield any significant results, especially for WLE.
  - Weight reduction scenarios to yield thermal relief are extremely aggressive and carry significant risk.
  - Have not identified method for determining if reduction in heat rate and heat load for bottom surface tiles is meaningful, especially for damage scenarios.

ENTRY OPTIONS
Forward Work Considerations

- No further work is planned for STS-107 entry options.
- No further work is planned for development of uncertified or contingency deorbit/entry profiles.
- If requested (as part of Return-to-Flight efforts, or otherwise), primary candidates have been identified for consideration:
  - High angle of attack (WLE relief).
  - Low angle of attack (bottom surface relief).
  - High drag and low drag cases.
- Process could yield pros/cons for WLE and other body points in each case - i.e. higher alpha reduces WLE heat rate, but increases heat load for other body points.
- Currently no way to know whether or not these efforts would yield a viable contingency capability to optimize for TPS damaged areas.

ENTRY OPTIONS
Backup Charts

- Orbiter Body Points Diagram
- Trajectory/TSEP Data Plots
- Consumables – Weight/CG Details
- Deployable Items – Weight/CG Details
- Weight Reduction Scenarios – Weight/CG Details
- Sample Wing Leading Edge Stagnation Temperature
- Sample Lower Surface Heat Rate
- Sample Drag Profile

ENTRY OPTIONS

Orbiter Body Points

TSEP model includes 29 body points used by USA Flight Design for commit to flight analysis.

Utilized to evaluate key body points individually:

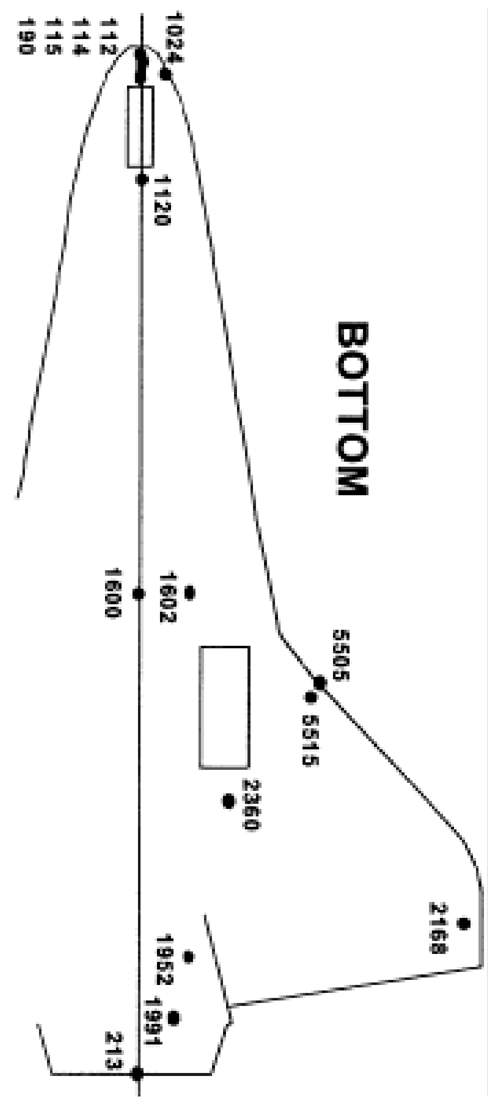
Wing Leading Edge Stagnation Temperature
(Body Point 5505 - RCC Panel 9)

Wing Lower Surface Heat Rate

(Body Point 2360 - aft of MLG door).

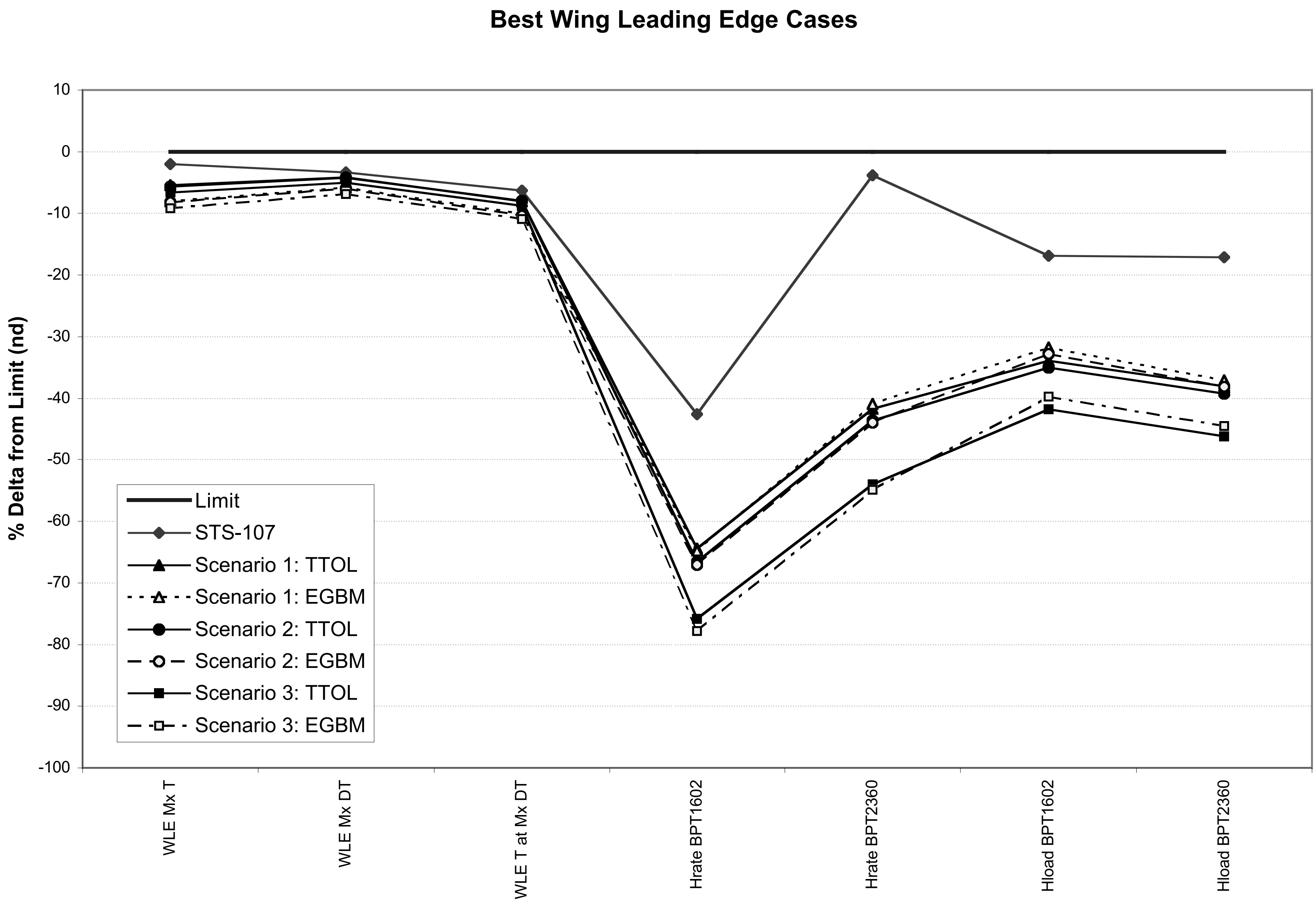
Mid Fuselage

(Body Point 1602 - forward of MLG door)

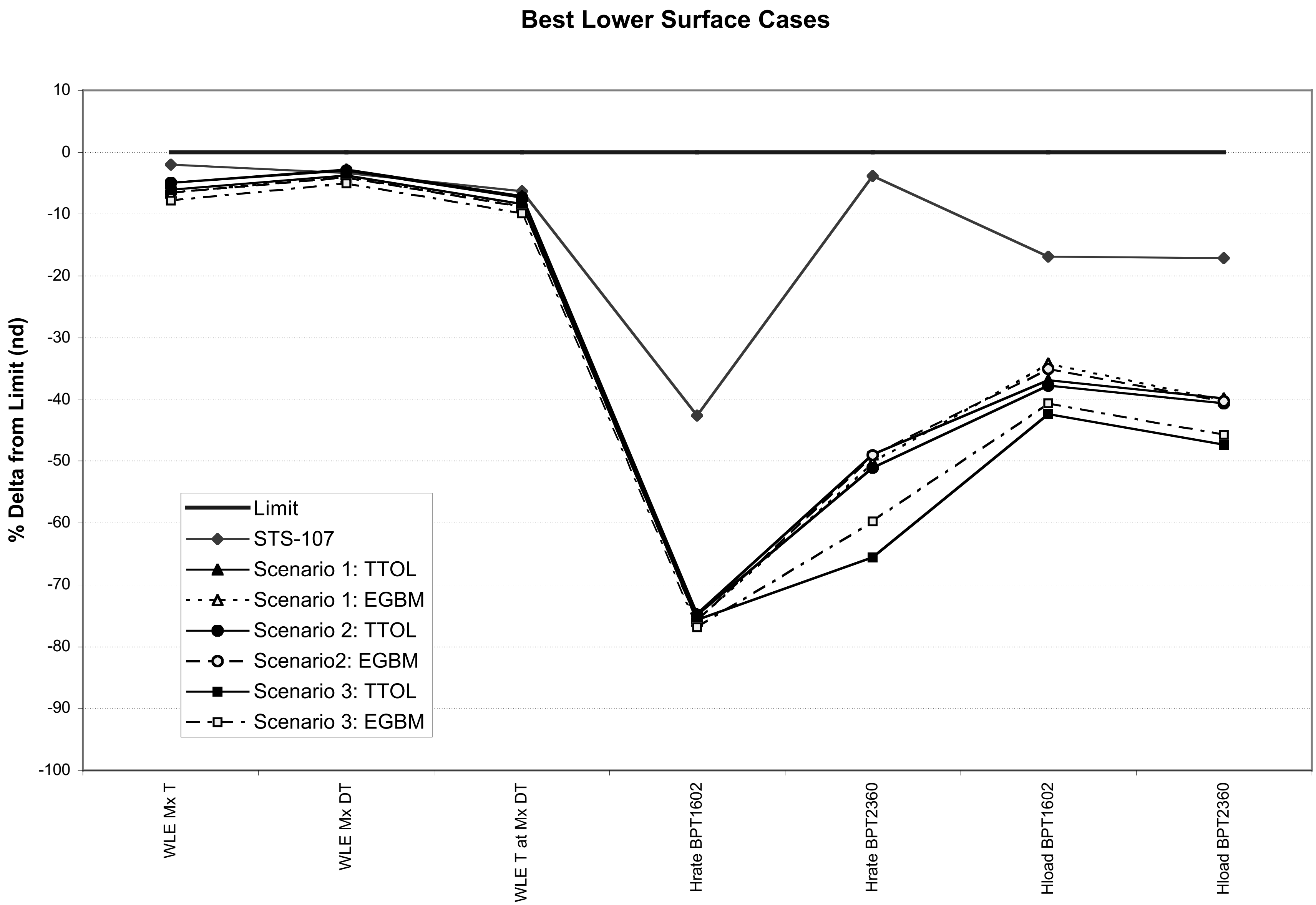


ENTRY OPTIONS
Trajectory/TSEP Data

(see following charts)

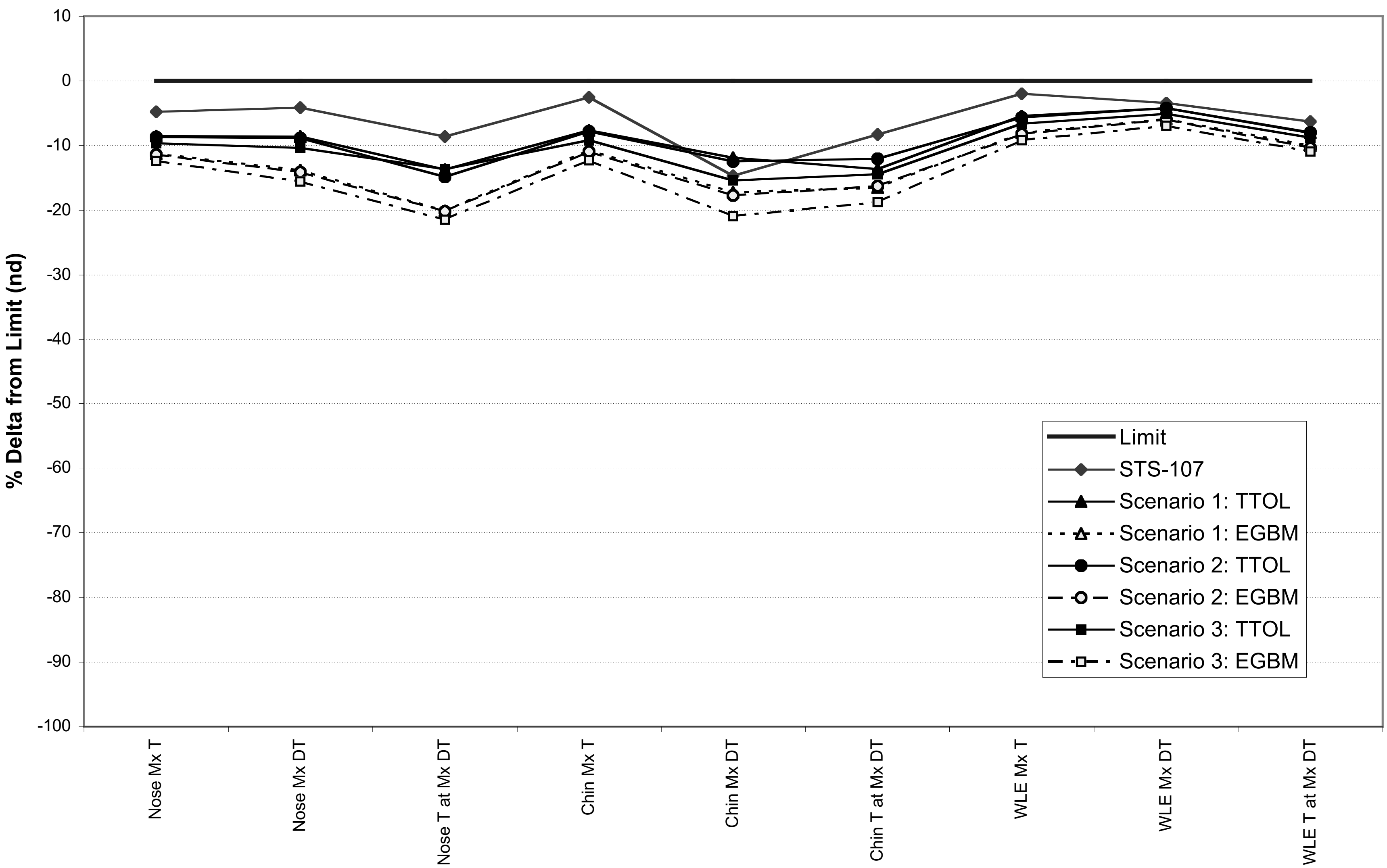


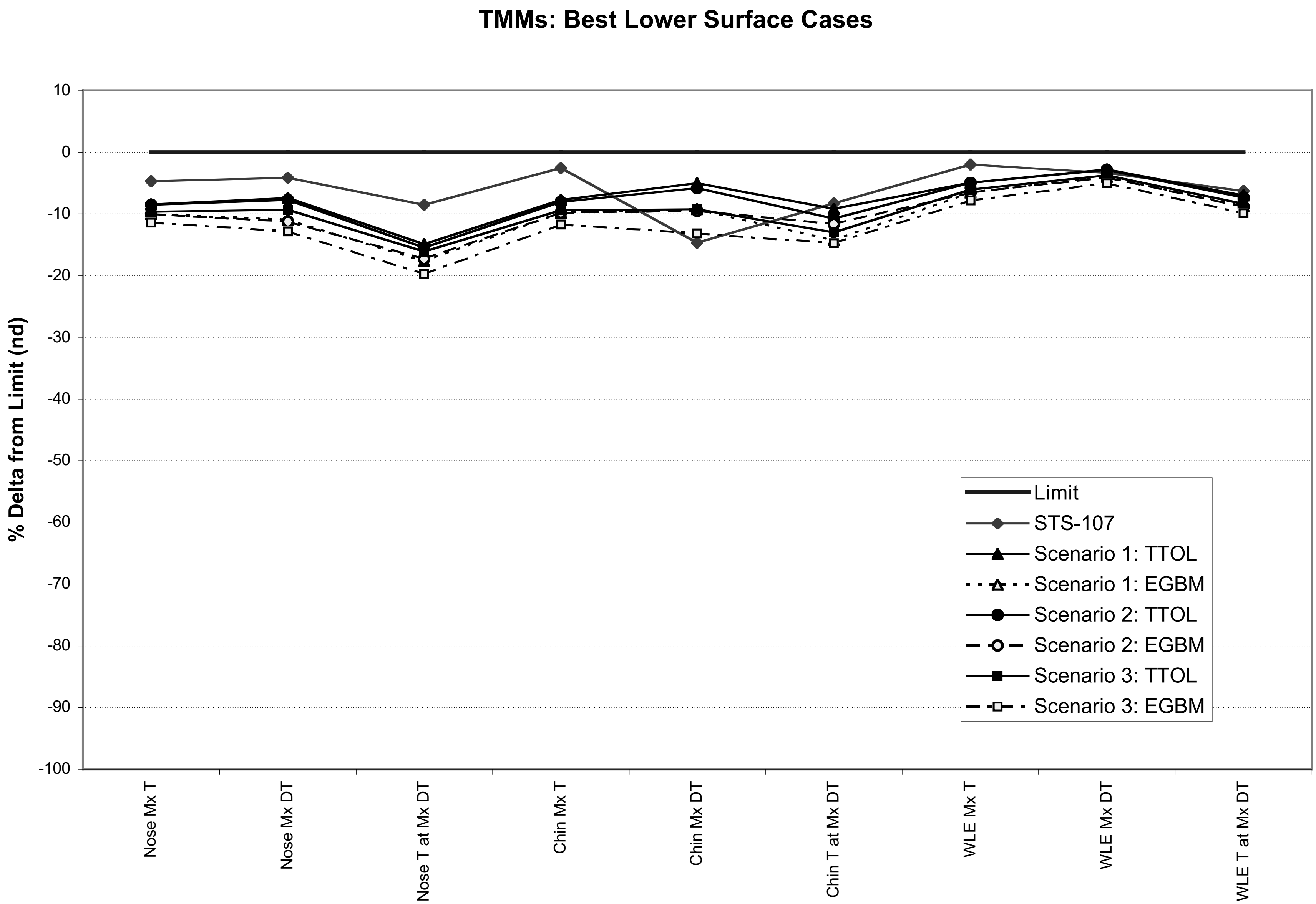
Best Wing Leading Edge Cases
% Delta from Limit (nd)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
WLE Mx T
WLE Mx DT
WLE T at Mx DT
Hrate BPT1602
Hrate BPT2360
Hload BPT1602
Hload BPT2360
Limit
STS-107
Scenario 1: TTOL
Scenario 1: EGBM
Scenario 2: TTOL
Scenario 2: EGBM
Scenario 3: TTOL
Scenario 3: EGBM



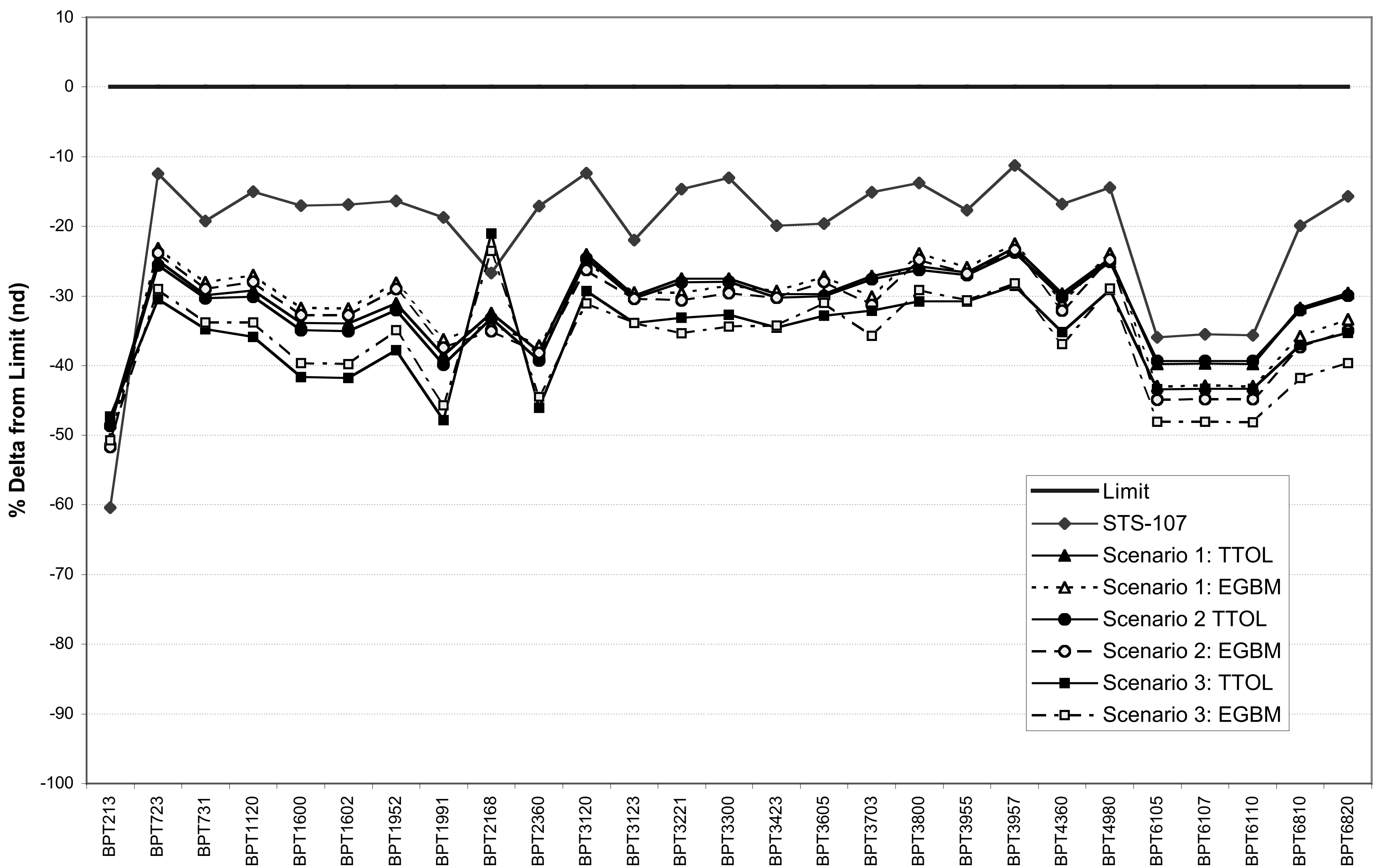
Best Lower Surface Cases
% Delta from Limit (nd)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Limit
STS-107
Scenario 1: TTOL
Scenario 1: EGBM
Scenario 2: TTOL
Scenario2: EGBM
Scenario 3: TTOL
Scenario 3: EGBM
WLE Mx T
WLE Mx DT
WLE T at Mx DT
Hrate BPT1602
Hrate BPT2360
Hload BPT1602
Hload BPT2360

TMMs: Best Wing Leading Edge Cases

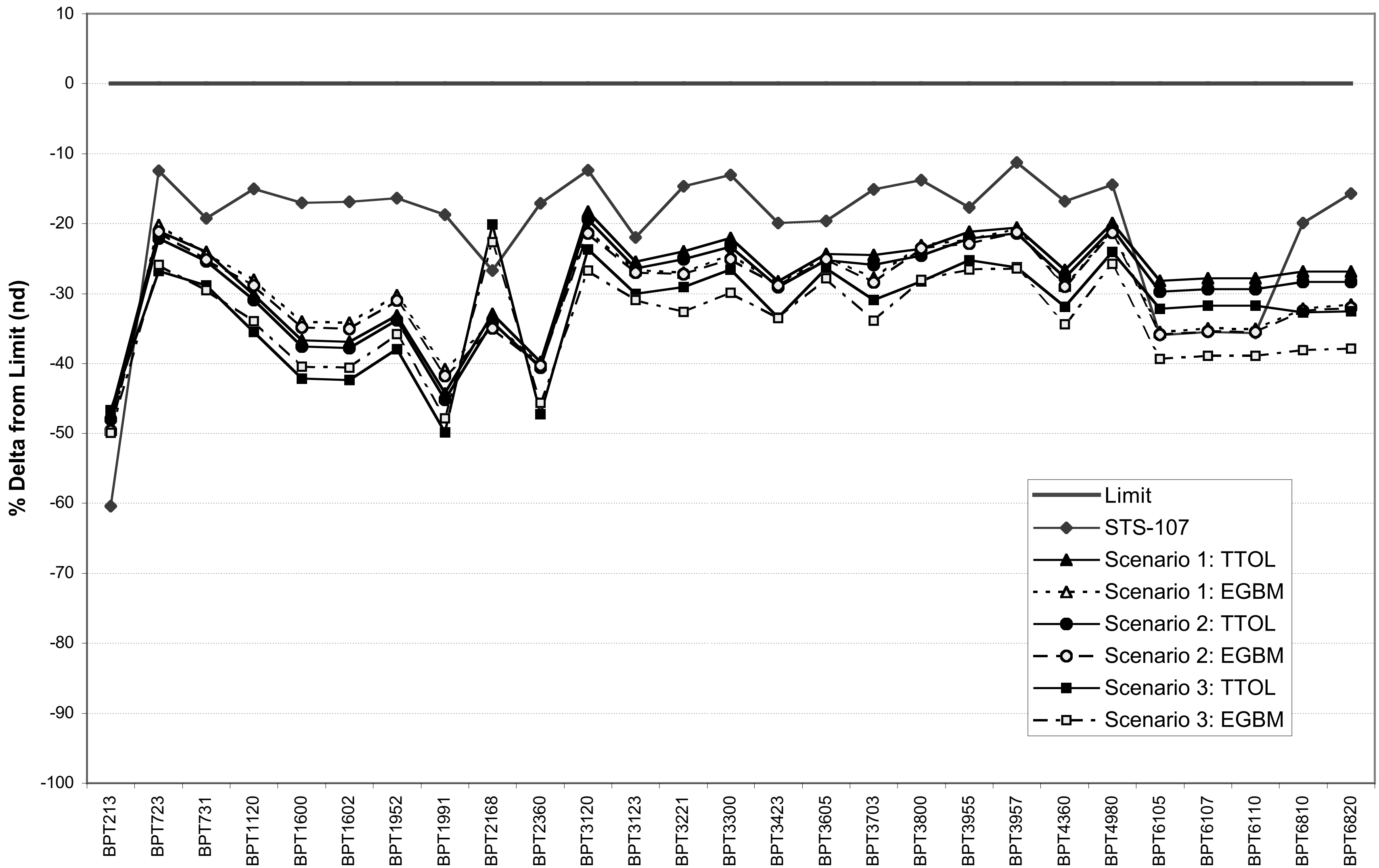


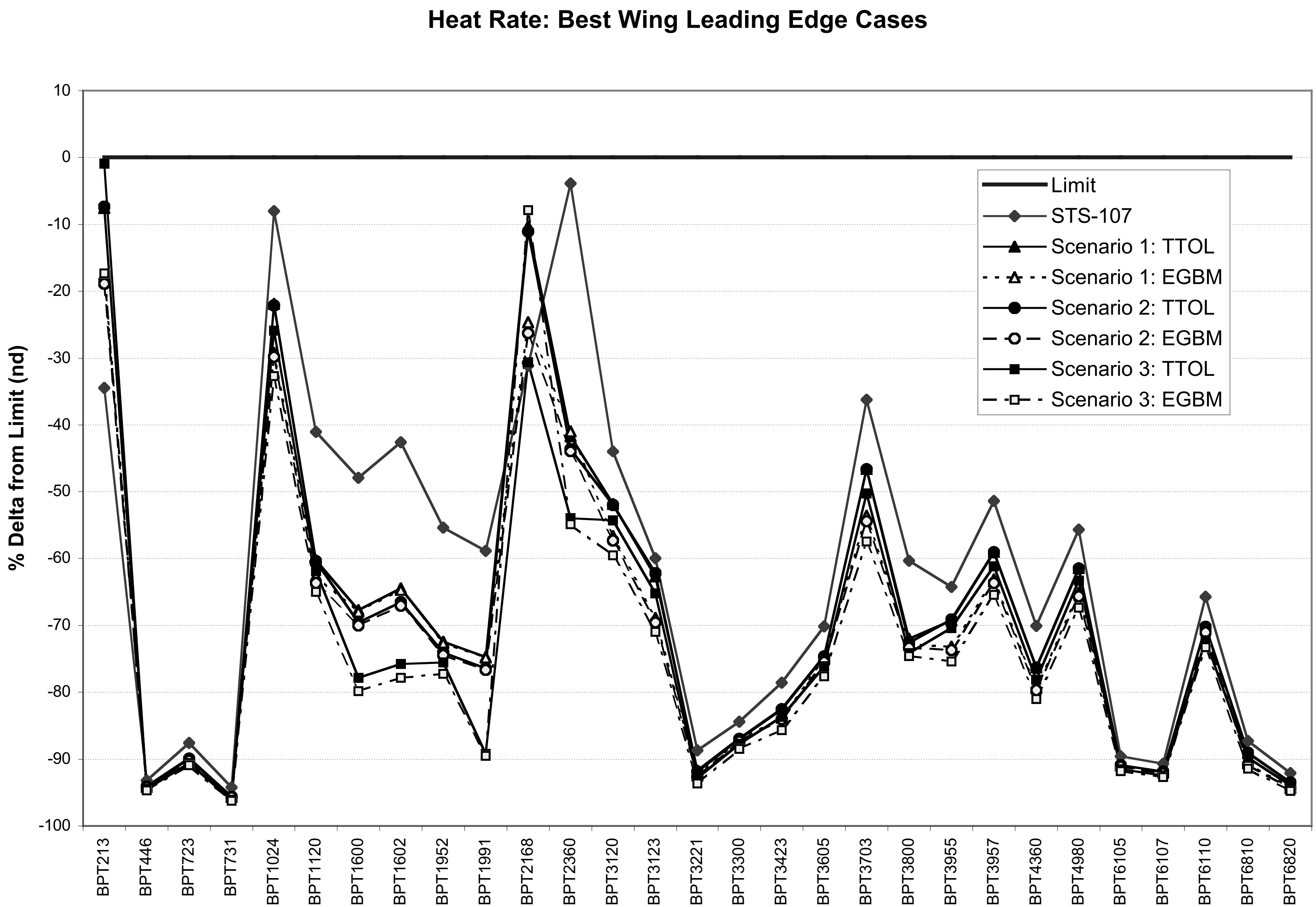

TMMs: Best Lower Surface Cases
% Delta from Limit (nd)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Nose Mx T
Nose Mx DT
Nose T at Mx DT
Chin Mx T
Chin Mx DT
Chin T at Mx DT
WLE Mx T
WLE Mx DT
WLE T at Mx DT
Limit
STS-107
Scenario 1: TTOL
Scenario 1: EGBM
Scenario 2: TTOL
Scenario 2: EGBM
Scenario 3: TTOL
Scenario 3: EGBM

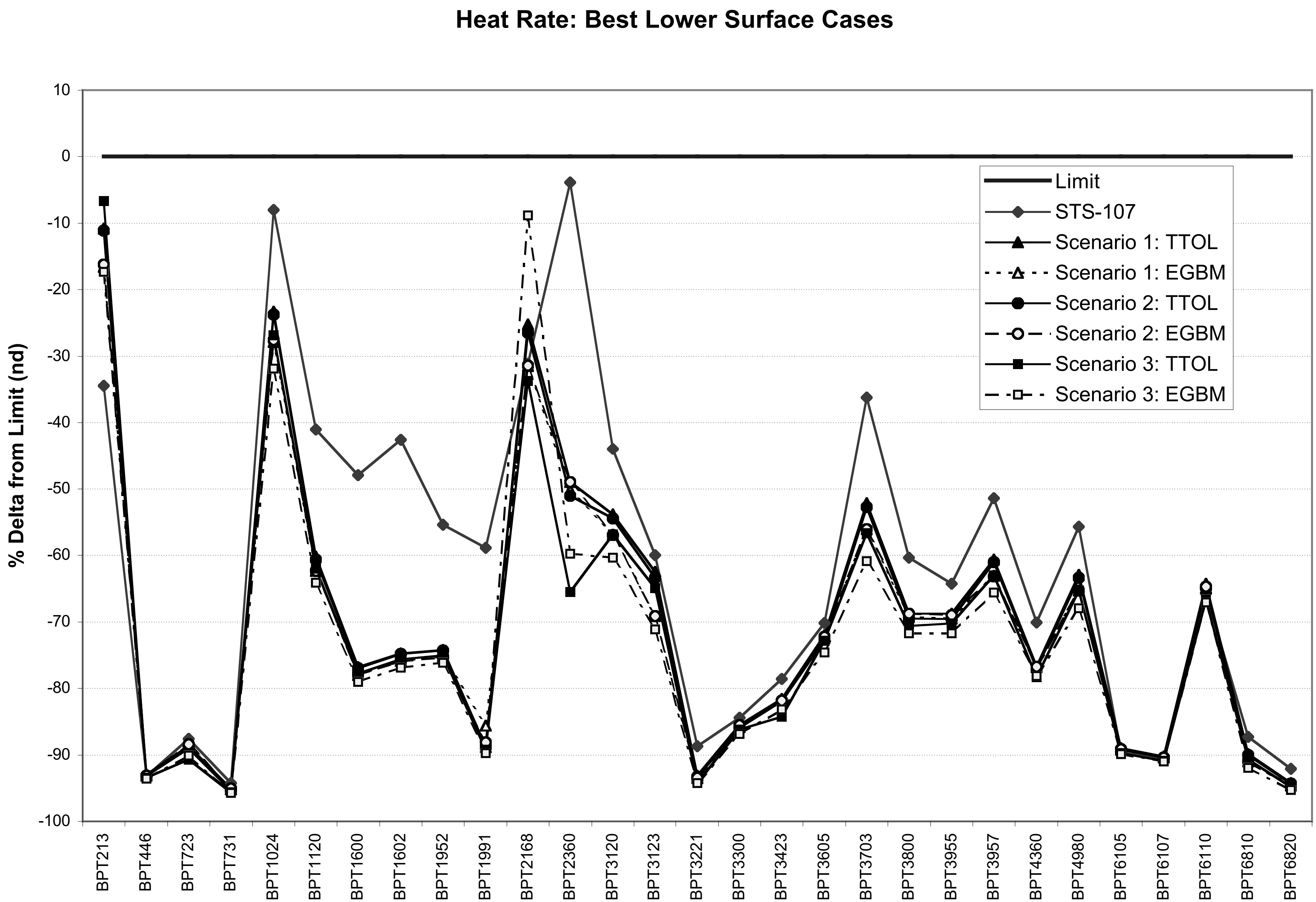
Heat Load: Best Wing Leading Edge Cases



Heat Load: Best Lower Surface Cases




Heat Rate: Best Wing Leading Edge Cases
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
% Delta from Limit (nd)
Limit
STS-107
Scenario 1: TTOL
Scenario 1: EGBM
Scenario 2: TTOL
Scenario 2: EGBM
Scenario 3: TTOL
Scenario 3: EGBM
BPT213
BPT446
BPT723
BPT731
BPT1024
BPT1120
BPT1600
BPT1602
BPT1952
BPT1991
BPT2168
BPT2360
BPT3120
BPT3123
BPT3221
BPT3300
BPT3423
BPT3605
BPT3703
BPT3800
BPT3955
BPT3957
BPT4360
BPT4980
BPT6105
BPT6107
BPT6110
BPT6810
BPT6820



Heat Rate: Best Lower Surface Cases
% Delta from Limit (nd)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Limit
STS-107
Scenario 1: TTOL
Scenario 1: EGBM
Scenario 2: TTOL
Scenario 2: EGBM
Scenario 3: TTOL
Scenario 3: EGBM
BPT213
BPT446
BPT723
BPT731
BPT1024
BPT1120
BPT1600
BPT1602
BPT1952
BPT1991
BPT2168
BPT2360
BPT3120
BPT3123
BPT3221
BPT3300
BPT3423
BPT3605
BPT3703
BPT3800
BPT3955
BPT3957
BPT4360
BPT4980
BPT6105
BPT6107
BPT6110
BPT6810
BPT6820

ENTRY OPTIONS
Consumables - Weight/CG Details

ECLSS	Δ Wt	Xcg	Ycg	Zcg
GN2 SYS 1	-51	976.6	-29.7	328.7
GN2 SYS 2	-35	707.8	89	328.7
GN2 TK-5	0	678	-89	329
NH3 TK-1	-46	1350	66	442
NH3 TK-2	-46	1370	67	443
POT H2O TK-A	-123	518	0	294
POT H2O TK-B	-90	534	0	293
POT H2O TK-C	-90	545	0.9	313
POT H2O TK-D	-90	528	0	311
WST H2O TK-1	-79	512	0	310

APU/HYD	Δ Wt	Xcg	Ycg	Zcg
APU N2H4 TK-1	-109	1400	-80	414
APU N2H4 TK-2	-113	1400	-85	381
APU N2H4 TK-3	-278	1400	80	414
HYD H2O TK-1	-9	1373	0	481
HYD H2O TK-2	-22	1393	0	483
HYD H20 TK-3	-29	1353	0	479

CRYO	Δ Wt	Xcg	Ycg	Zcg
O2 TK-1	-302.9	778.5	-77.5	308
H2 TK-1	-67.7	891	-76	306.1
O2 TK-2	-286.8	721.5	77.5	308
H2 TK-2	-66.7	835	76	307.1
O2 TK-3	-205.7	1115.5	58.3	294.8
H2 TK-3	-60.9	1009.8	-73.9	302.9
O2 TK-4	0.4	1065.2	-76.5	300.5
H2 TK-4	0.2	891	76	306.1
O2 TK-5	-0.5	949.3	-70	306.2
H2 TK-5	0.0	949.3	69	302.8
O2 TK-6	-340.1	1257.7	56.7	392
H2 TK-6	-6.3	1262.5	28.5	350
O2 TK-7	-254.0	1257.7	-56.7	392
H2 TK-7	-7.7	1262.5	-28.5	350
O2 TK-8	-1.3	1257.7	48.7	439
H2 TK-8	-0.4	1262.5	0	399.4
O2 TK-9	0.2	1257.7	-48.7	439
H2 TK-9	-0.4	1262.5	0	454

PROP	Δ Wt	Xcg	Ycg	Zcg
OMS FU R	(-41)	1444.9	72.262	501.53
OMS OX R	(-152.6)	1444.6	110.48	461.96
OMS FU L	(-51)	1444.9	-72.26	501.53
OMS OX L	(-130.6)	1444.7	-110.5	461.97
RCS FU FWD	0	317	-24	365
RCS OX FWD	0	317	24	365
RCS FU AFT R	-252.3	1340	67	490
RCS OX AFT R	-397.9	1340	99	457
RCS FU AFT L	-271.2	1340	-67	490
RCS OX AFT L	-427.7	1340	-99	457

NOTE: Items shown in "( )" not included in scenario buildups

ENTRY OPTIONS
Deployable Items - Weight/CG Details

	Δ Wt	Xcg	Ycg	Zcg
Spacehab	-18071	892.3	-3.5	392.4
Freestar	-4428	1119.8	0.7	396.9
Radiator Panel	-1657	944	-55	450

Deployables from Freestar Elements

	Δ Wt	Xcg	Ycg	Zcg
MEIDEX	-428	1152	40	404
SOLSE-02	-423	1152	-40	404
CVX-2 Exp Package	-364	1093	13	400
CVX-2 Avn Package	-361	1093	-13	400
SEM	-315	1093	-40	400

Deployables from Spacehab Systems

	Δ Wt	Xcg	Ycg	Zcg
PDU	-85.00	815	6	332
FSCU	-22.00	807	28	332
CSA	-29.50	844	28	332
Fwd Inverters (3)	-13.71	859	33	332
Aft Inverters (3)	-13.71	972	1	332
Scrubber	-15.00	879	30	332
Fwd Luminaries (4)	-17.00	841	0	445
Aft Luminaries (4)	-12.48	943	0	445
ARS Fan	-3.29	844	-10	332
Smoke Detectors (2)	-4.80	878	0	332
Dew Point Elec + 2 Sensors	-9.30	840	1	332
ACS	-34.70	801	19	402
DMU	-12.80	859	-32	332
EDSMU	-47.36	801	0	414
EDS Hub	-21.35	801	-62	386
ECU	-9.24	878	-28	332
CEWL Pumps (2)	-56.00	938	29	332
APDU	-93.00	932	12	332
MCP	-34.50	801	-19	402
CO2 Box	-6.73	942	-9	332
Fwd EXCPs (3)	-26.20	794	0	394
Aft EXCPs (4)	-38.60	989	0	394
Halon Bottle 1 (filled)	-5.94	793	-57	434
Halon Bottle 2 (filled)	-5.94	793	57	434
Halon Bottle 3 (filled)	-5.94	800	-62	374
Halon Bottle 4 (filled)	-5.94	793	57	374
Halon Bottle 5 (filled)	-5.94	885	12	330
Halon Bottle 6 (filled)	-5.94	990	57	434
Halon Bottle 7 (filled)	-5.94	990	-57	434
Halon Bottle 8 (filled)	-5.94	990	57	374
Halon Bottle 9 (filled)	-5.94	988	12	330
Halon Bottle 10 (filled)	-5.94	885	-12	330
Handheld Halon 1 (filled)	-5.25	793	-16	386
Handheld Halon 2 (filled)	-5.25	896	20	438
SEBS (2)	-35.40	801	-19	420
CST (dry)	-45.00	982	-29	332
Air Balancing Box	-30.20	962	-27	332
Hab Fan Assembly	-35.00	947	-26	332
Air Bypass Valve Assy	-26.70	930	-26	332
Condensing Hx (dry)	-60.22	905	-8	332
PPO2 Sensors (2)	-3.62	796	0	402
PPCO2 Sensors (2)	-7.26	878	0	332
Total Pressure Sensor	-0.58	796	0	402
Temperaure Sensors (9)	-4.77	890	0	332
Water Seperator	-18.42	927	-6	332
WFCV	-4.65	815	-31	332
Exp HX 1 (dry)	-7.70	931	24	332
Exp HX 2 (dry)	-7.70	835	-24	332
CEWL HX (dry)	-7.70	900	31	332
Water Metering Valves (11)	-9.13	860	0	332
Water Flow meters (2)	-15.20	815	-32	332
Water Temp Sensors (7)	-3.71	830	-10	332
VSU	-8.00	801	-43	386

ENTRY OPTIONS
Deployable Items - Weight/CG Details (cont.)

Deployables from Spacehab Payloads

	Δ Wt	Xcg	Ycg	Zcg		Δ Wt	Xcg	Ycg	Zcg
ARMS	-369.10	801	43	386	AST 10/1	-78.92	983	0	362
EIU#2	-19.33	801	43	434	AST 10/2	-59.58	857	-31	368
STARS-Bootes	-65.02	983	-19	362	CPCG-PCF	-77.00	983	19	438
ERISTO	-71.50	983	-19	374	CIBX	-76.50	983	19	415
PhAB4	-202.61	850	-31	390	MSTRS	-20.00	801	19	438
EOR/F	-146.01	983	0	420	ZCG	-108.84	983	43	380
TEHM	-116.89	983	-19	408	FRESH	-367.60	801	31	420
Centrifuge	-32.54	801	-43	403	Biotube	-71.57	983	43	362
FAST	-130.31	983	43	432	SH FDF	-60.60	928	55	395
APCF	-75.15	983	19	403	Shared PGSC	-16.97	832	-31	430
Biobox	-116.70	983	19	374	Camcorders (2)	-30.00	801	-62	406
VCD FE (rack)	-944.27	915	55	390	35mm Camera	-22.63	837	-31	368
CM-2 (2 racks)	-2801.65	910	-55	390	Media Bag	-19.72	933	55	408
SAMS FF	-24.30	983	0	426	Stowage Bag/Straps	-5.00	842	-31	378
MGM	-305.28	983	43	403	Crew Ops H/W	-29.96	801	-43	374
BDS-05	-181.37	983	-10	386	Trash Stow	-19.28	801	-43	362
Ergometer	-106.08	801	62	402	Supplemental Equip	-44.70	982	-43	368
HLS AMS	-60.49	983	62	386	SSP Clothes/LiOH	-113.44	837	-31	385
EIU#3	-19.33	983	-43	412					

ENTRY OPTIONS
Deployable Items - Weight/CG Details (cont.)

Deployables from Middeck

	Δ Wt	Xcg	Ycg	Zcg		Δ Wt	Xcg	Ycg	Zcg
MF57A - Pantry Food	-61	434	9	407	MA9J - Clothing	-36	524.5	61.3	355.7
MF43C - IFM Tools	-69	433.6	-9.2	395.8	MA9L - Clothing	-41	524.5	61.3	344.5
MF57C - Crew Support	-20	433.6	9.3	395.8	MA9N -	-73	524.5	61.3	333.4
MF14E - LiOH Cans 49-57	-44	434.1	-46.2	384.7	MA16D - CMPCG	-66.9	524.5	42.9	389
MF28E - Printer Trays, GIRA	-26	434.1	-27.7	384.7	MA16F - Menu Food	-50	524.5	42.9	377.9
MF43E - IFM Breakout Box, etc.	-38	434.1	-9.2	384.7	MA16G - Clothing	-40	524.5	42.9	366.8
MF57E - Fresh Food	-58	434.1	9.3	384.7	MA16J - Clothing	-40	524.5	42.9	355.7
MF71E - HLS/CEBAS, ZCG Autoclaves	-36	434.1	27.7	384.7	MA16L - Clothing	-40	524.5	42.9	344.5
MF28G/H - Biopack	-61.23	434.7	-27.7	373.6	MA16N - Menu Food	-51	524.5	42.9	333.4
MF28G/H - Biopack	-61.23	435.3	-27.7	362.5	MAR	-100	482.1	-59.3	368.9
MF43G - Post Insertion	-46	434.7	-9.2	373.6	A/L Ceiling Bag - Clothing, Food, etc.	-107.5	560	0	410
MF57G - HLS	-36.72	434.7	9.3	373.6	A/L Floor Bag-LiOH Cans 31-48, etc.	-165.6	560	0	340
MF71G - Osteo	-60.6	434.7	27.7	373.6	Volume B - Hygiene	-85	521	79	375
MF14H - Menu Food	-46	435.3	-46.2	362.5	Volume 3B - OCAC	-30.5	535	43.5	370.1
MF43H - Biopack CB	-30.1	435.3	-9.2	362.5	A16 - 70mm Camera Bag, etc.	-55.43	562	15	429
MF57H - PTCU 1	-59	435.3	9.3	362.5	A17 - CC Sys Bag, 35mm Cam, etc.	-52.01	562	-15	429
MF71H - PTCU 2	-58.1	435.3	27.7	362.5	MD52M - (EDO LiOH Box) ATCO, etc.	-61.65	492	0	311
MF14K - Menu Food	-51	435.8	-46.2	351.4	MD52C - (Volume D) LiOH Cans 11-30	-137	439	0	314
MF28K - Med Kits, Dosimeter	-47	435.9	-27.7	351.4	MD75C - (Volume E) OFK, PPK	-65.5	437	27.7	329.2
MF43K - FDF and SH FDF	-45	435.9	-9.2	351.4	MD80R - (Volume G) Cont UCD's, etc.	-45	525	42	317
MF57K - FDF	-59	435.9	9.3	351.4	WMC - Towels and Resupply Items	-75.6	546	-49	365
MF71K - ZCG, Autoclaves Box	-54.5	435.9	27.7	351.4	Galley	-76.7	452	-64	353
MF14M - Menu food	-55	436.5	-46.2	340.3	Ergometer	-115	488.2	-10.3	357.4
MF28M - COAS, 70mm Film, etc.	-40	436.5	-27.7	340.3	Flight Deck Fire Extinguisher	-6.2	481.6	-0.3	459
MF43M - PTCU 3	-50.3	436.5	-9.2	340.3	Middeck Fire Extinguisher (Side Hatch)	-6.2	546	-49	365
MF57M - PTCU 4	-48.5	436.5	9.3	340.3	Middeck Fire Extinguisher (Airlock)	-6.2	560	0	410
MF71M - BDS-D5	-45.48	436.5	27.7	340.3	Av Bay Fan 1A	-4.1	406	-27	340
MF14O - Menu Food	-50	437	-46.2	329.2	Av Bay Fan 2B	-4.1	406	27	340
MF28O - Meidex, Solse, PGSC's	-47	437	-27.7	329.2	Av Bay Fan 3A	-9.38	560	51	350
MF71O - Bric	-65.5	437	27.7	329.2	IMU Fans A,C	-5.95	434	9	407
MA9D - Menu Food	-41	524.5	61.3	389	Cabin Fan B	-5.6	461	4	315
MA9F - Clothing	-42	524.5	61.3	377.9	Humidity Separator	0	461	4	315
MA9G - Clothing	-39	524.5	61.3	366.8					

ENTRY OPTIONS
Deployable Items - Weight/CG Details (cont.)

Deployables from Flight Deck / Avionics

LRU	SLOT	#	MASS	Location	Δ Wt	X CG	Y CG	Z CG
GPC	2,4	2	60	Av Bay 2	-120	406	27	340
GPC	3	1	60	Av Bay 3	-60	406	27	340
MDM	LF1	1	38.5	Av Bay 1	-38.5	406	-27	340
MDM	FF4, PL2	2	38.5	Av Bay 2	-77	406	27	340
MDM	FF3	1	38.5	Av Bay 3	-38.5	406	27	340
ADTA	2, 4	2	11	Av Bay 2	-22	406	27	340
ADTA	3	1	11	Av Bay 1	-11	406	-27	340
TACAN	1	1	30	Av Bay 1	-30	406	-27	340
TACAN	2	1	30	Av Bay 2	-30	406	27	340
TACAN	3	1	30	Av Bay 3	-30	406	27	340
MLS (RF & DEC)	1	1	23.5	Av Bay 1	-23.5	406	-27	340
MLS (RF & DEC)	2,3	2	23.5	Av Bay 2	-47	406	27	340
RA	2	1	4.5	Av Bay 2	-4.5	406	27	340
BFC	1	1	12.5	Av Bay 1	-12.5	406	-27	340
BFC	2,3	2	12.5	Av Bay 2	-25	406	27	340
MMU	2	1	25	Av Bay 2	-25	406	27	340
NSP	2	1	19	Av Bay 3	-19	406	27	340
AA	4	1	2.3	Av Bay 1	-2.3	406	-27	340
AA	2,3	2	2.3	Av Bay 2	-4.6	406	27	340
OPS Recorder	1,2	2	43	Av Bay 2	-86	406	27	340

LRU	SLOT	#	MASS	Location	Δ Wt	X CG	Y CG	Z CG
PCMMU	2	1	30	Av Bay 2	-30	406	27	340
HUD	2	1	20	Av Bay 2	-20	406	27	340
HUDE	2	1	40	Av Bay 3B	-40	406	27	340
RHC	A	1	10	A6	-10	568	-3	477
DDU	A	1	23	A6	-23	568	-3	477
MDU	AFT 1, CRT 4	2	17	R12	-34	541	53	445
PL INTEROG	n/a for 107	0	46.5		0	0	0	0
PDI		1	27.5	Av Bay 1	-27.5	406	-27	340
PL Recorder		1	43	Av Bay 1	-43	406	-27	340
KUSP		1	41	Av Bay 3B	-41	406	27	340
KU EA 1		1	45	Av Bay 3	-45	406	27	340
KU EA 2		1	34	Av Bay 3	-34	406	27	340
KU DEA (PLB)		1	83	PLB	-83	576	94	414
KU DMA (PLB)		1	89	PLB	-89	576	94	414
PSP	1,2	2	18	Av Bay 2	-36	406	27	340
COMSEC	2	1	46.5	Av Bay 3	-46.5	406	27	340
FM SIG PROC		1	12	Av Bay 3	-12	406	27	340
Color TV Monitors		2	40	L12	-80	560	-45	443
FM XMTR	1,2	2	6.8	Av Bay 3	-13.6	406	27	340

Groundrules/Assumptions

1. Reduce to zero fault tolerance for GNC functions & Comm.
2. Retain BFS for PLBD ops, antenna management, and SM insight (no engage capability).
3. Relies on GPS 2 only for nav updates.
4. Data recording capability sacrificed.

ENTRY OPTIONS
Weight Reduction Scenarios - Weight/CG Details

Scenario 1: *Total weight savings = 20,387 lbs*

Weight/cg changes from items A, B, C, D, and E

	Weight	Xcg	Ycg	Zcg
Entry Interface	214088.6	1098.60	-0.18	370.38
TAEM	213611.1	1097.66	-0.17	370.20
Landing	213529.8	1099.37	-0.16	367.50

Scenario 2: *Total weight savings = 22,924 lbs*

Weight/cg changes from items A, B, C, E, and F

	Weight	Xcg	Ycg	Zcg
Entry Interface	211551.6	1098.35	-0.26	370.11
TAEM	211074.1	1097.39	-0.25	369.93
Landing	210992.8	1099.12	-0.24	367.19

ENTRY OPTIONS
Weight Reduction Scenarios - Weight/CG Details

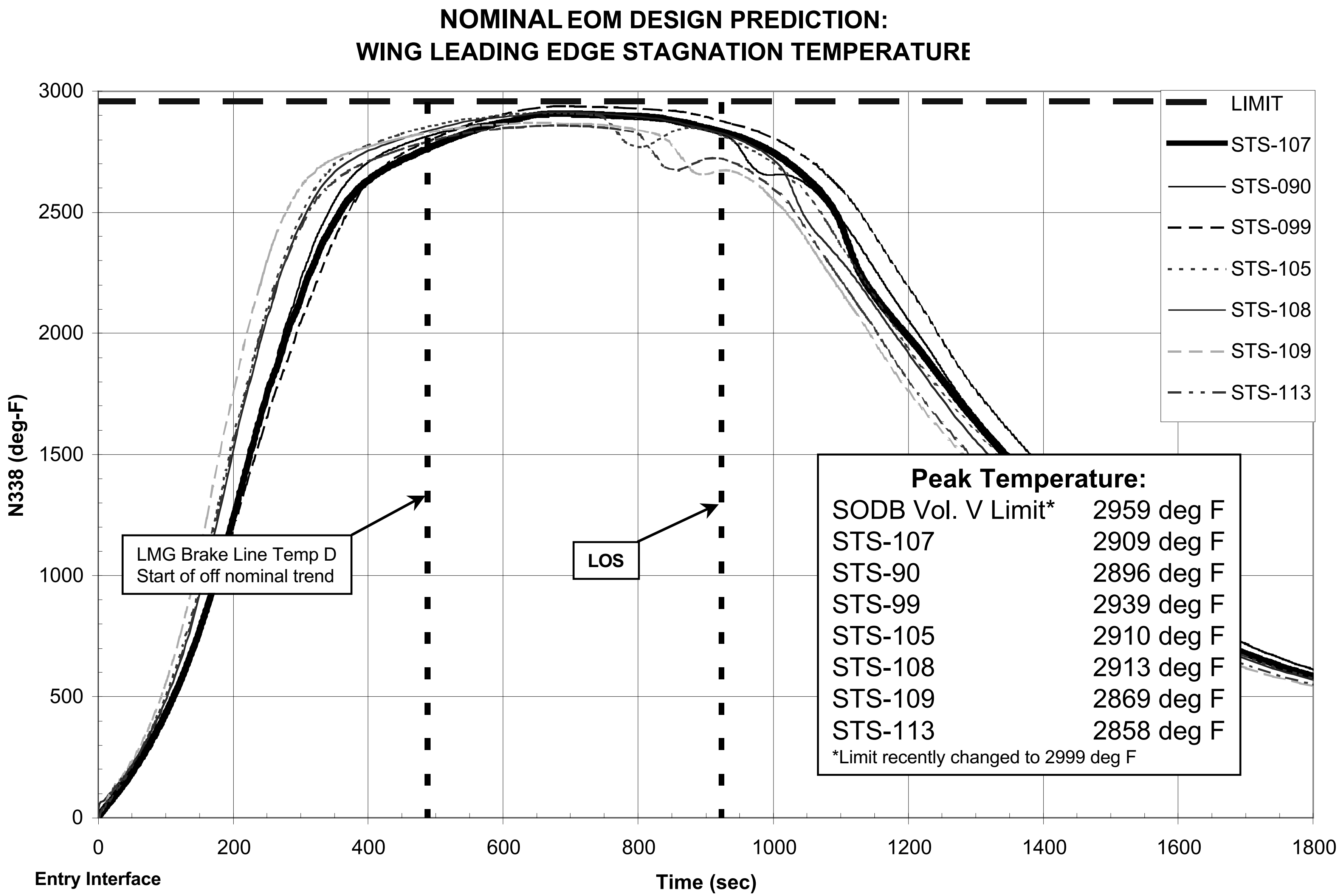
Scenario 3: ***Total weight savings = 31,321 lbs***

Weight/cg changes from items A, B, F, and G

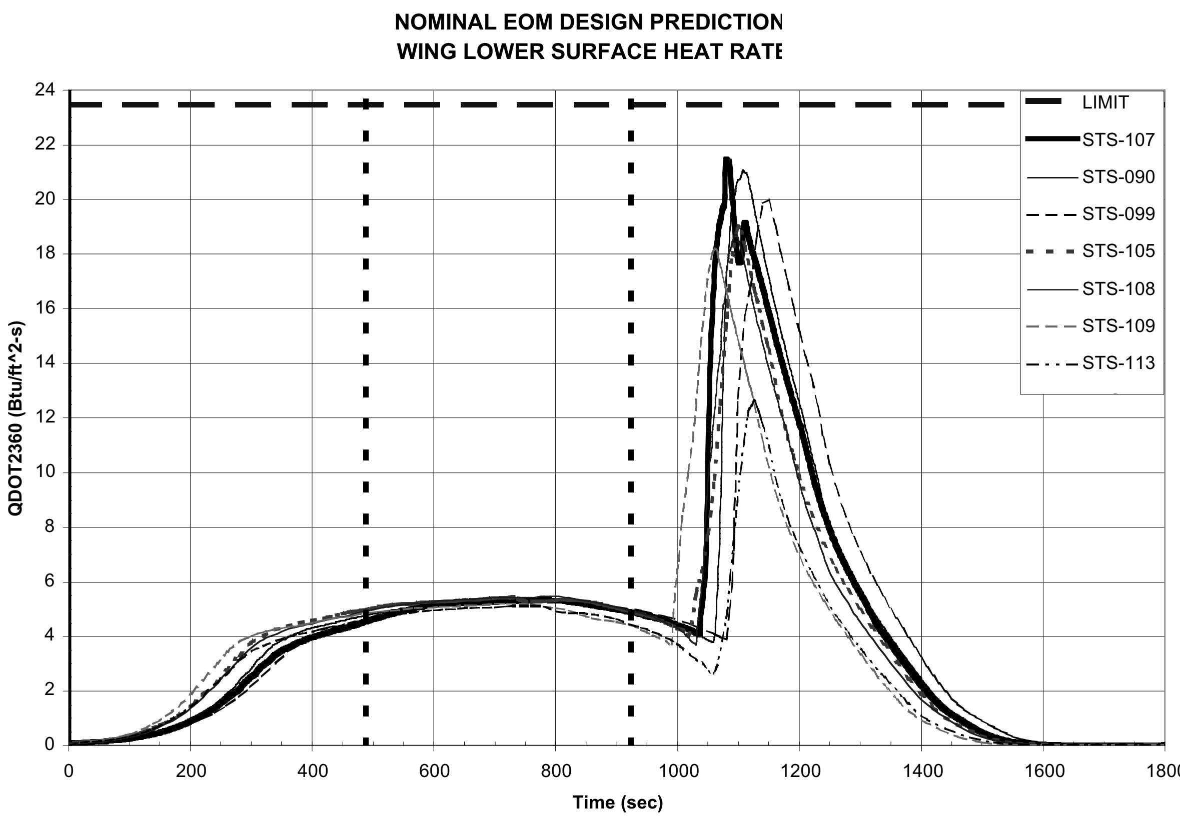
	Weight	Xcg	Ycg	Zcg
Entry Interface	203154.9	1107.83	-0.68	369.52
TAEM	202677.4	1106.85	-0.67	369.33
Landing	202596.1	1108.66	-0.66	366.48

- For a baseline comparison, the following are the predicted end-of-mission mass properties from STS-107.

	Weight	Xcg	Ycg	Zcg
Entry Interface	234477.0	1078.91	-0.56	371.97
TAEM	233999.5	1078.00	-0.55	371.81
Landing	233918.2	1079.56	-0.54	369.35


NOMINAL EOM DESIGN PREDICTION:
WING LEADING EDGE STAGNATION TEMPERATURE
N338 (deg-F)
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
1600
1800
Entry Interface
Time (sec)
LIMIT
STS-107
STS-090
STS-099
STS-105
STS-108
STS-109
STS-113
LMG Brake Line Temp D
Start of off nominal trend
LOS
Peak Temperature:
SODB Vol. V Limit* 2959 deg F
STS-107 2909 deg F
STS-90 2896 deg F
STS-99 2939 deg F
STS-105 2910 deg F
STS-108 2913 deg F
STS-109 2869 deg F
STS-113 2858 deg F
*Limit recently changed to 2999 deg F

ENTRY OPTIONS
Lower Surface Heat Rate – Multiple Flights



ENTRY OPTIONS
Sample Drag Profile