Case Study of 767 Horizontal Stabilizer

- Goals of this class
  - Carry through the topics of this course on one product
    - Look in detail at a real aircraft structural assembly
    - Define and flow down KCs
    - Compare different assembly methods
      - conventional one based on fixtures
      - proposed one based on part-to-part mating features
    - Draw datum flow chains for them
    - Study the economics

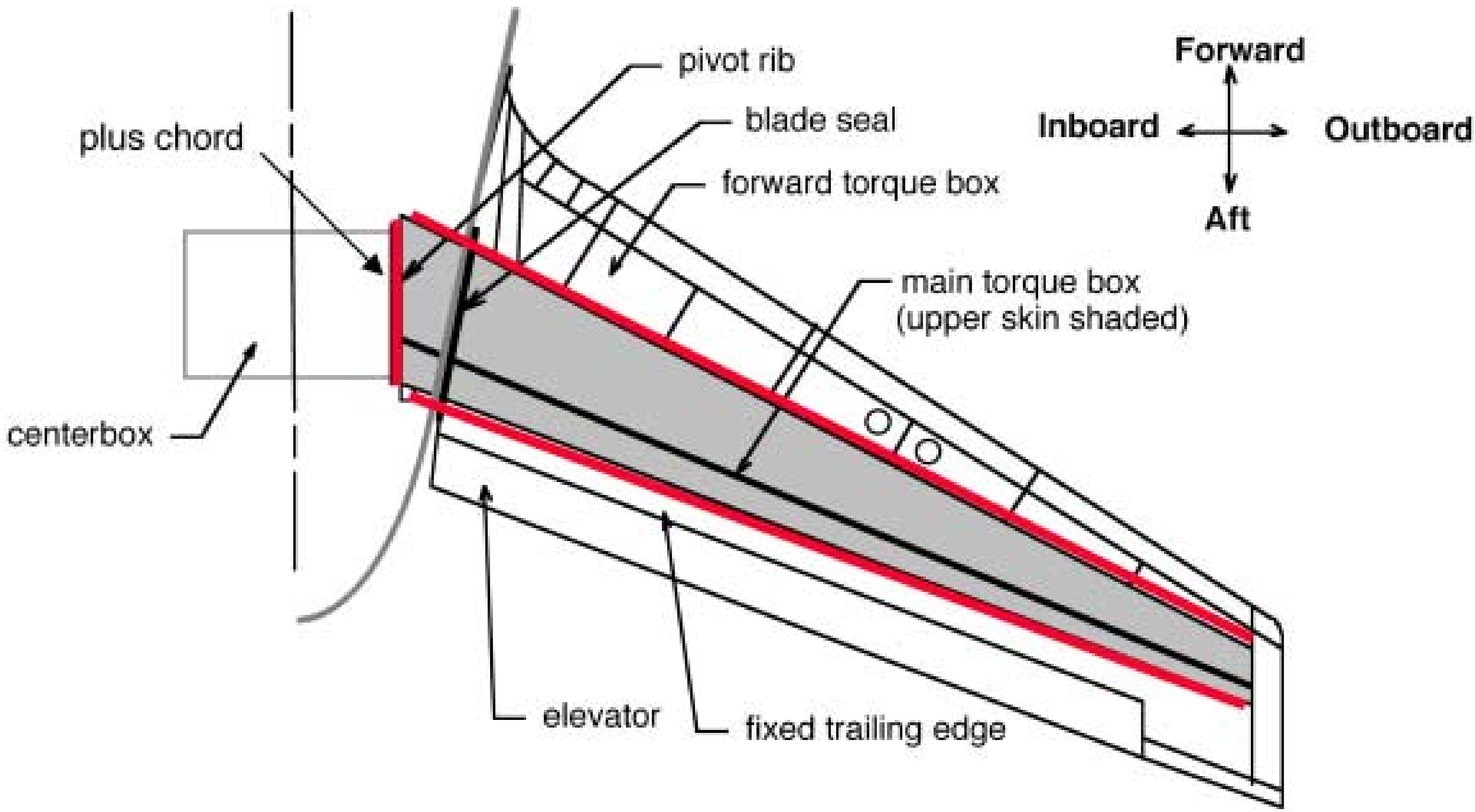
History of 767 Horizontal Stabilizer Project

- Fast/Flexible Manufacturing Project 1996
- Coordinated Aircraft and Auto industry projects
- Vought Aircraft partner via LAI
- Vought's goal: cut costs, earn more Boeing business
- Vought's hypothesis: convert from fixed to flexible assembly tooling
- Vought's focus of project: 767 H. S. upper wing subassembly

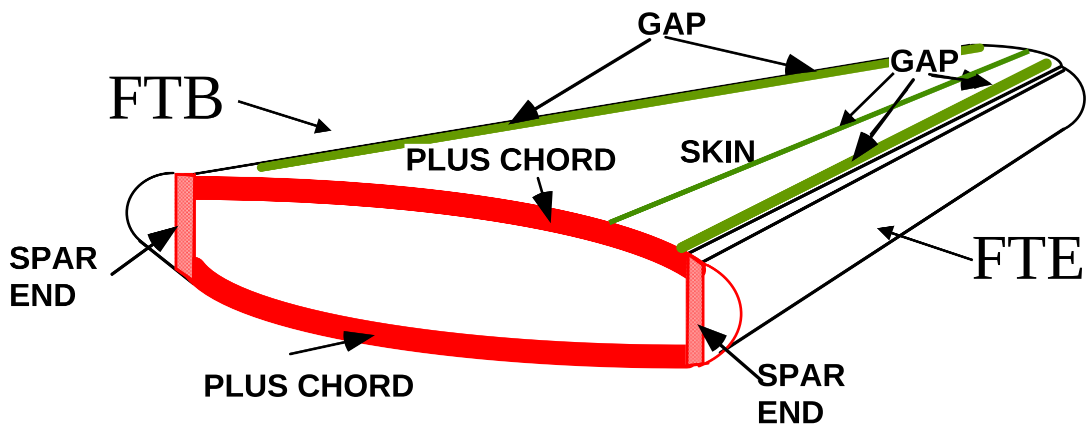
Our Challenge: How To Do This

- Available data
  - Existing tooling
  - No history, people, drawings
  - Evidence of errors in tooling
- Our process
  - Understand **goals** of existing process
  - Reverse engineer from the top down
  - Expand scope of study to complete horizontal stabilizer
  - Look up the supply chain to Boeing to get the requirements
  - Generate new process to achieve agreed goals

Structure of Horizontal Stabilizer



Top Level Key Characteristics

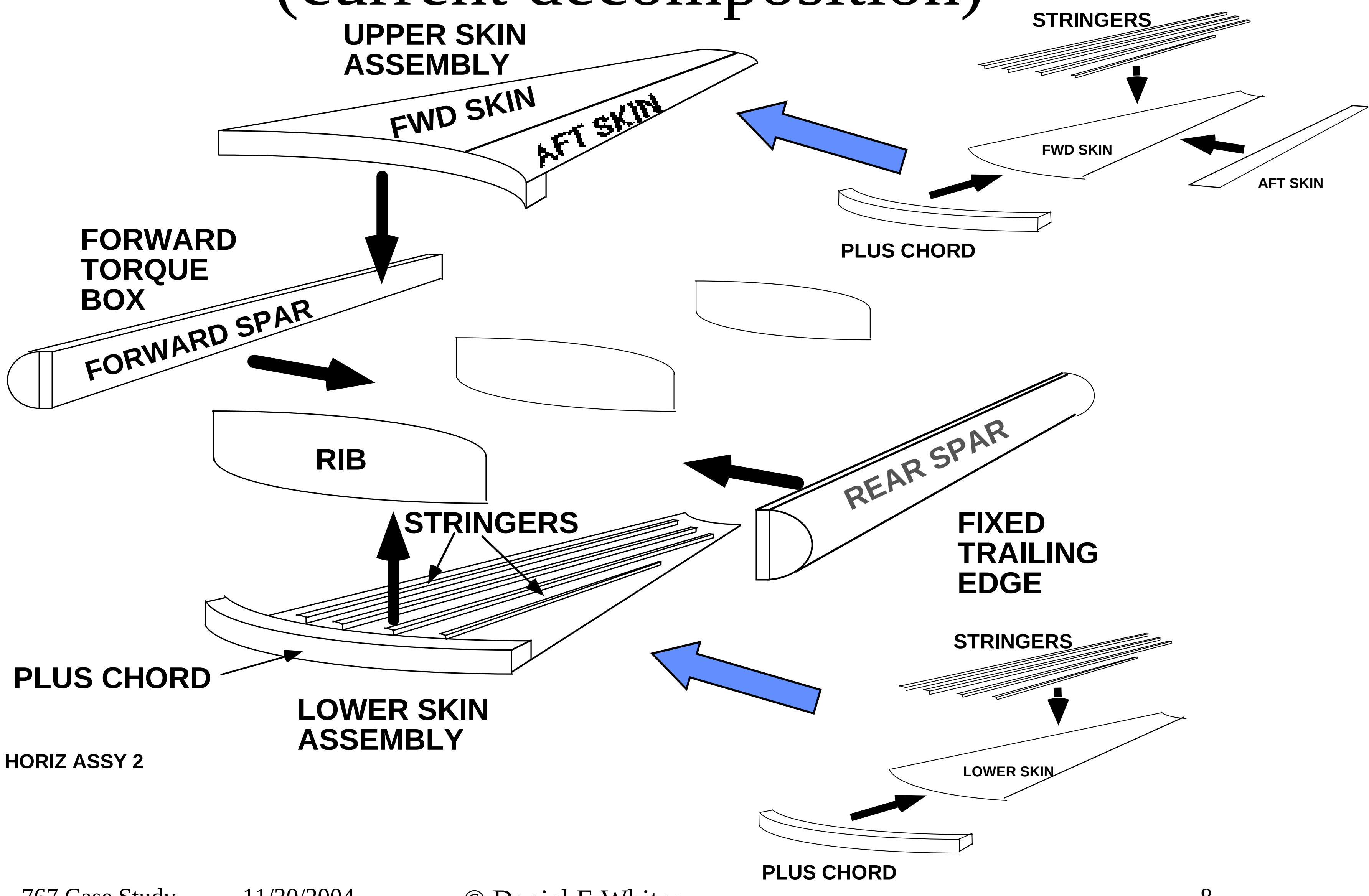


AERODYNAMICS
(gap betw skin and FTB & FTE)
(gap between skins)

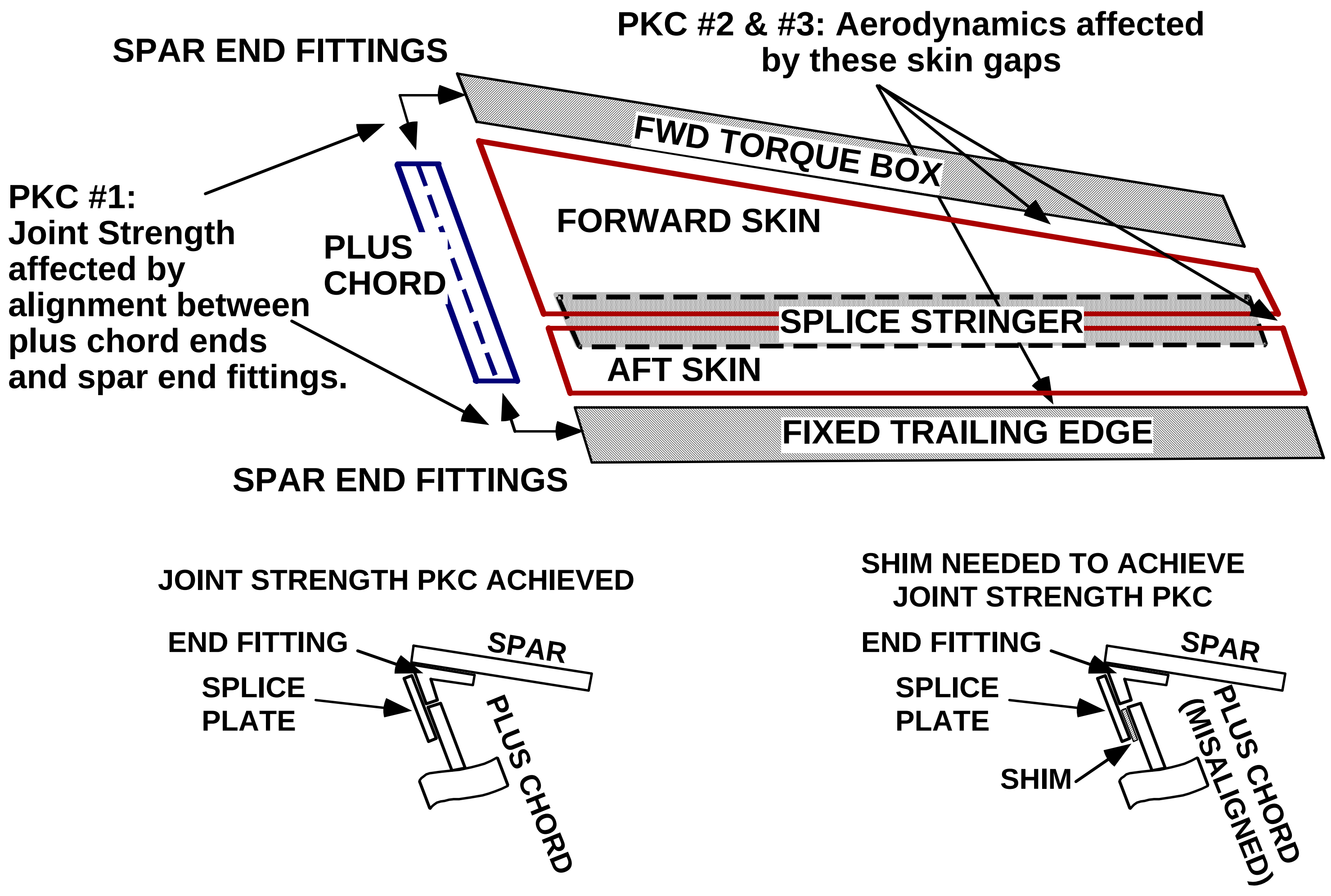
STRENGTH
(based on joining plus chords and ends of spars)

HORIZ ASSY 2

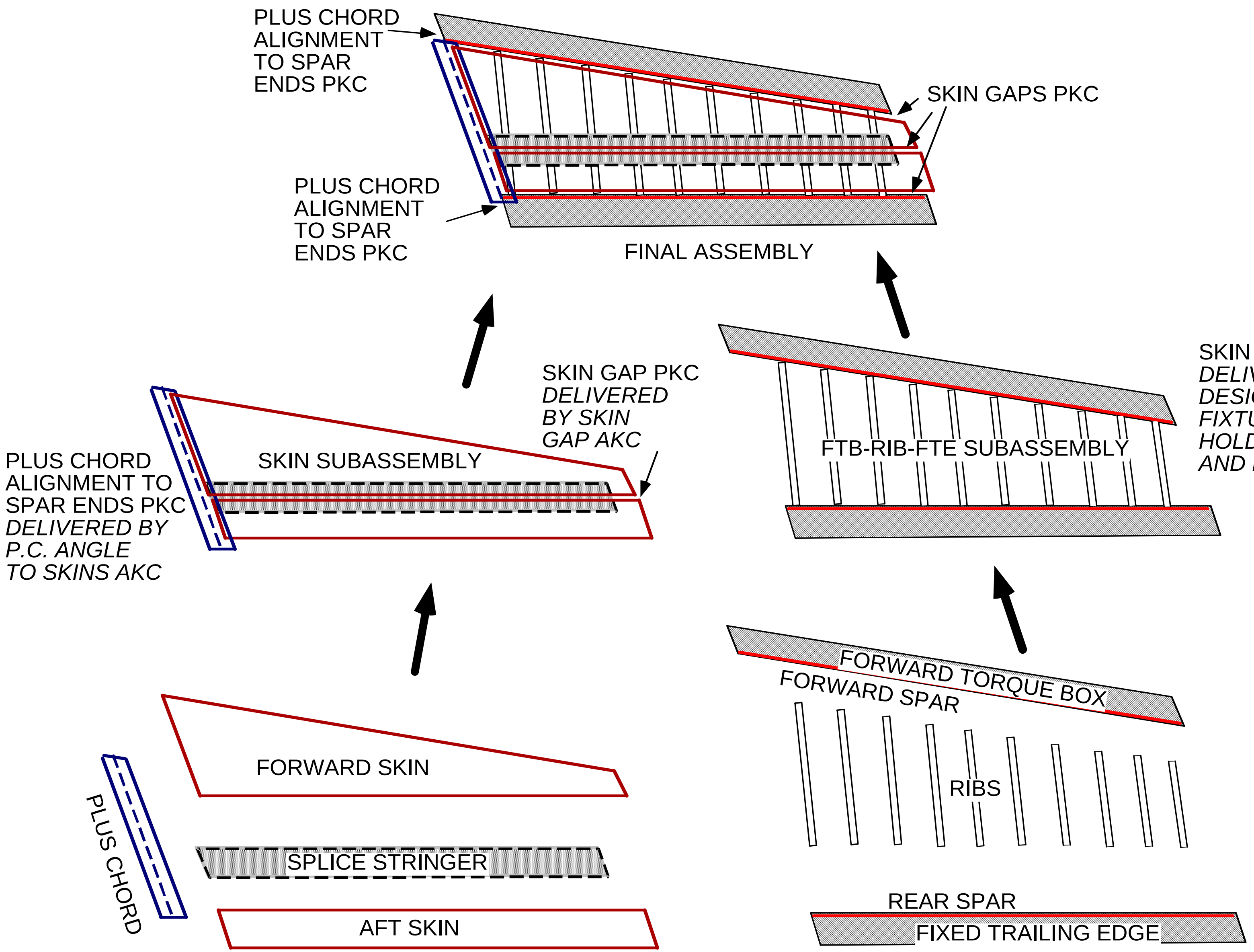
Horizontal Stabilizer Subassemblies (current decomposition)



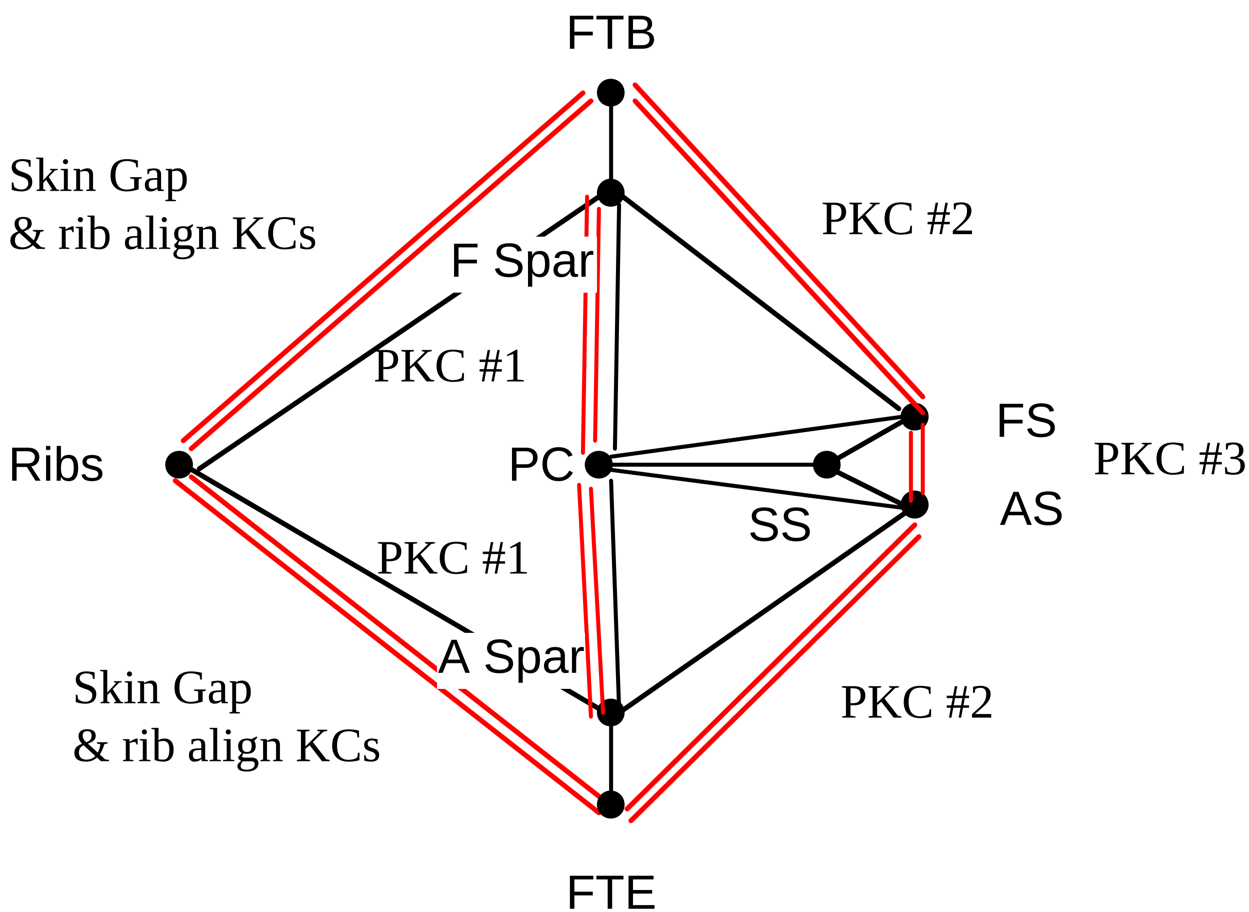
PKCs for Horizontal Assembly



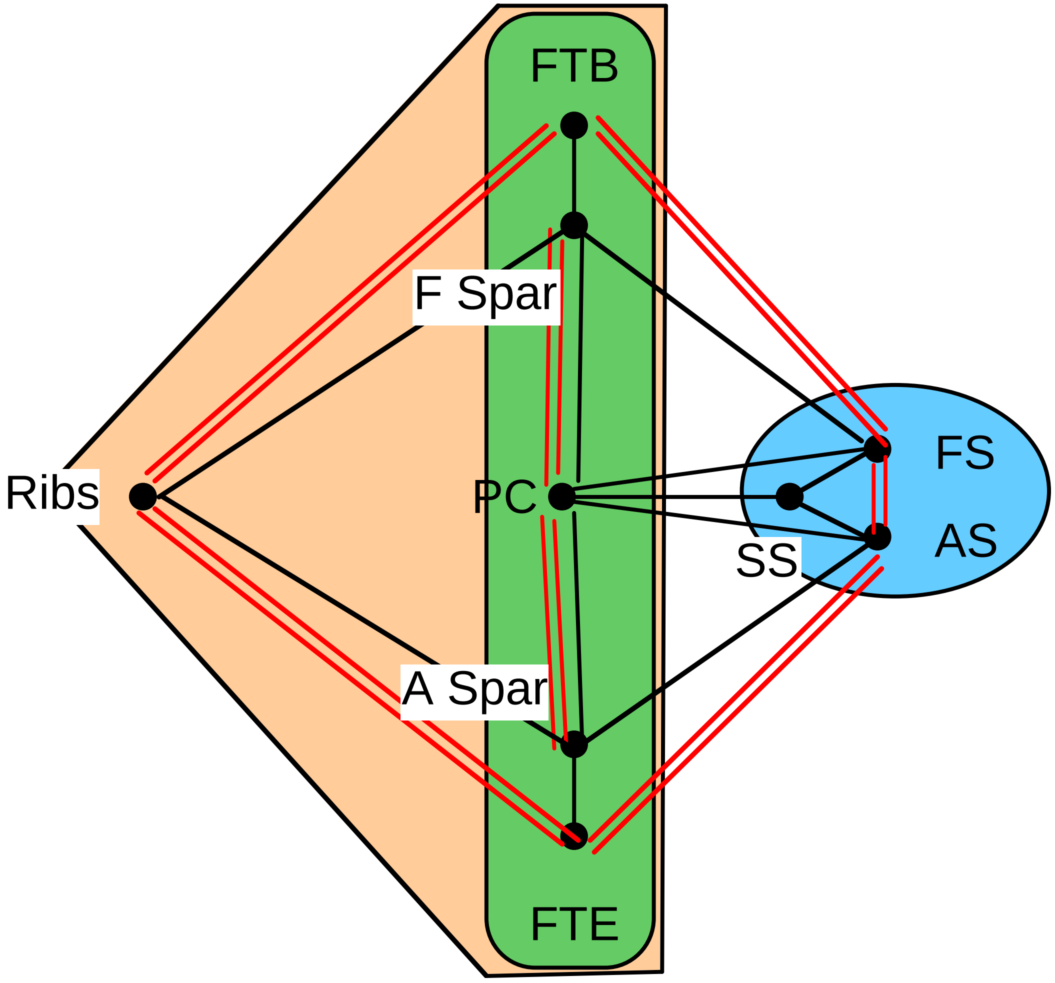
Current Total Process



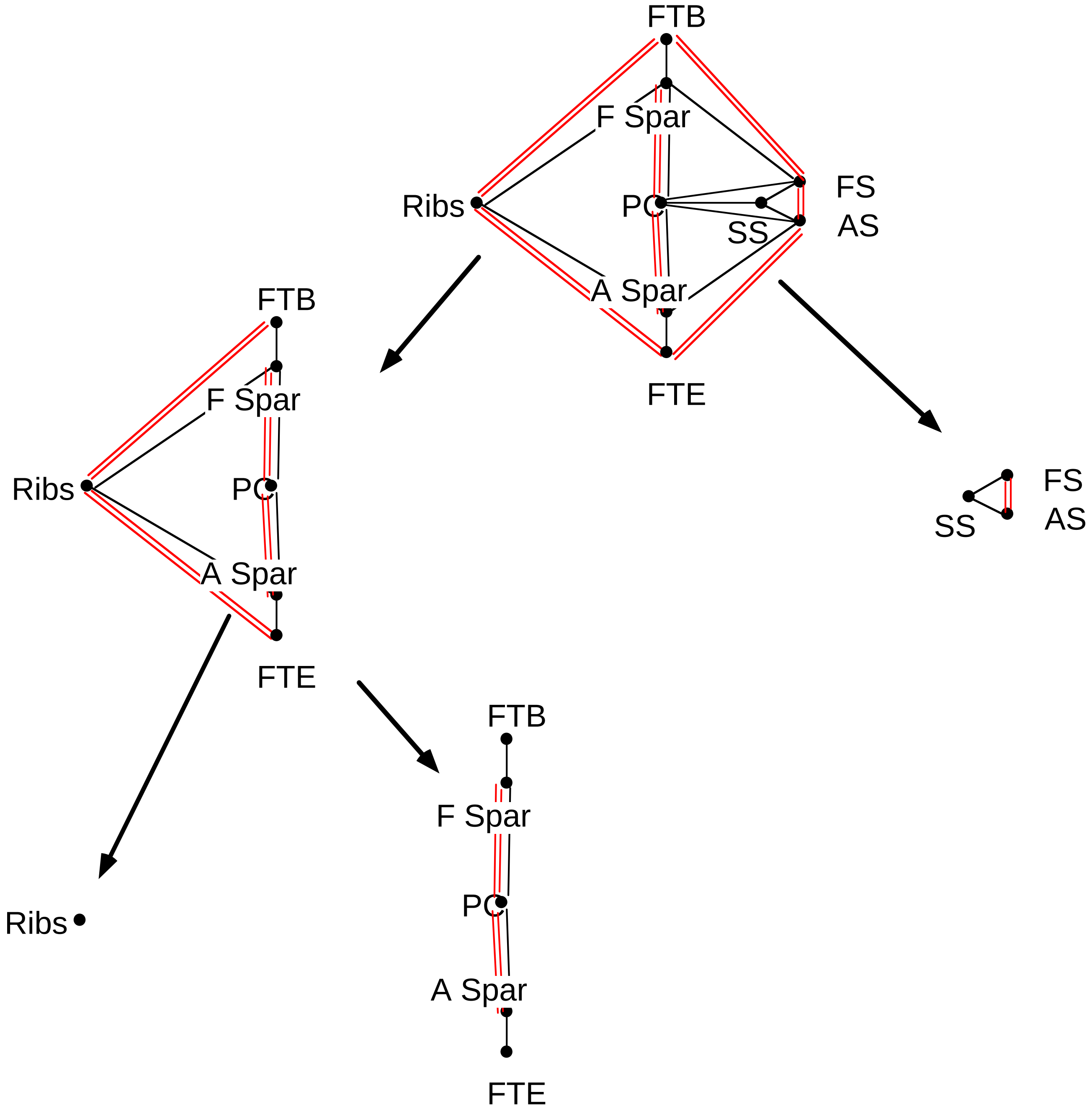
Top-Level KCs



Product Decomposition Based on Independent KCs



Decomposition/Subassemblies Based on Independent KCs

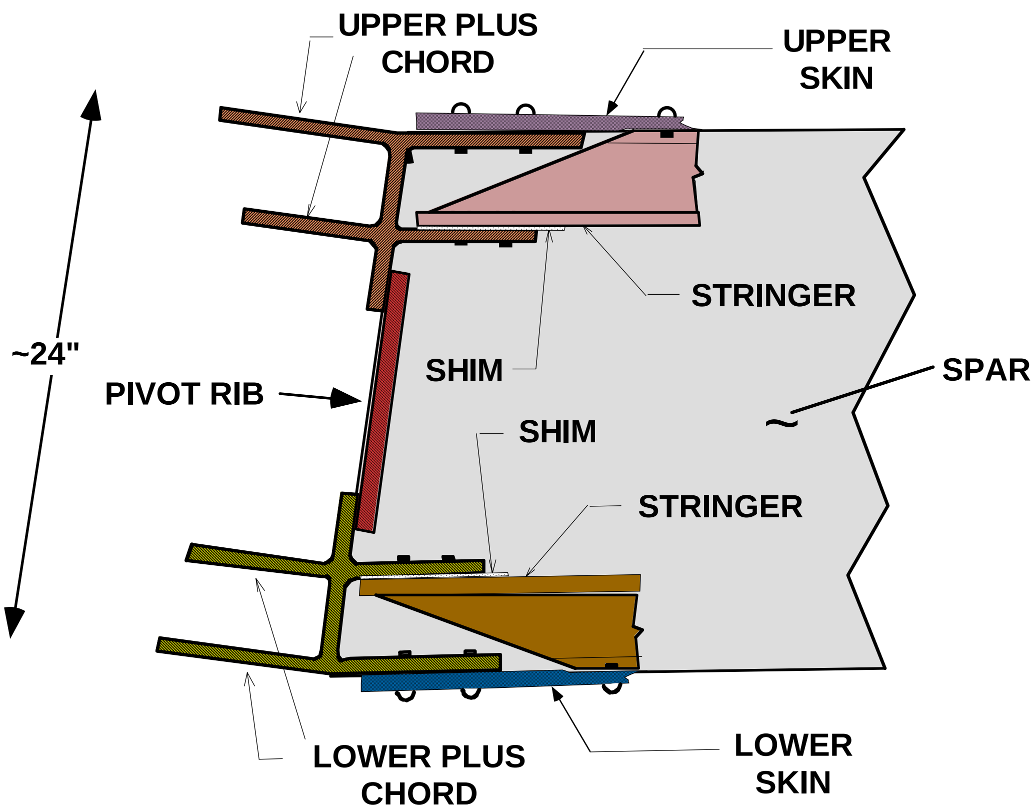


Sob

Unfortunately,

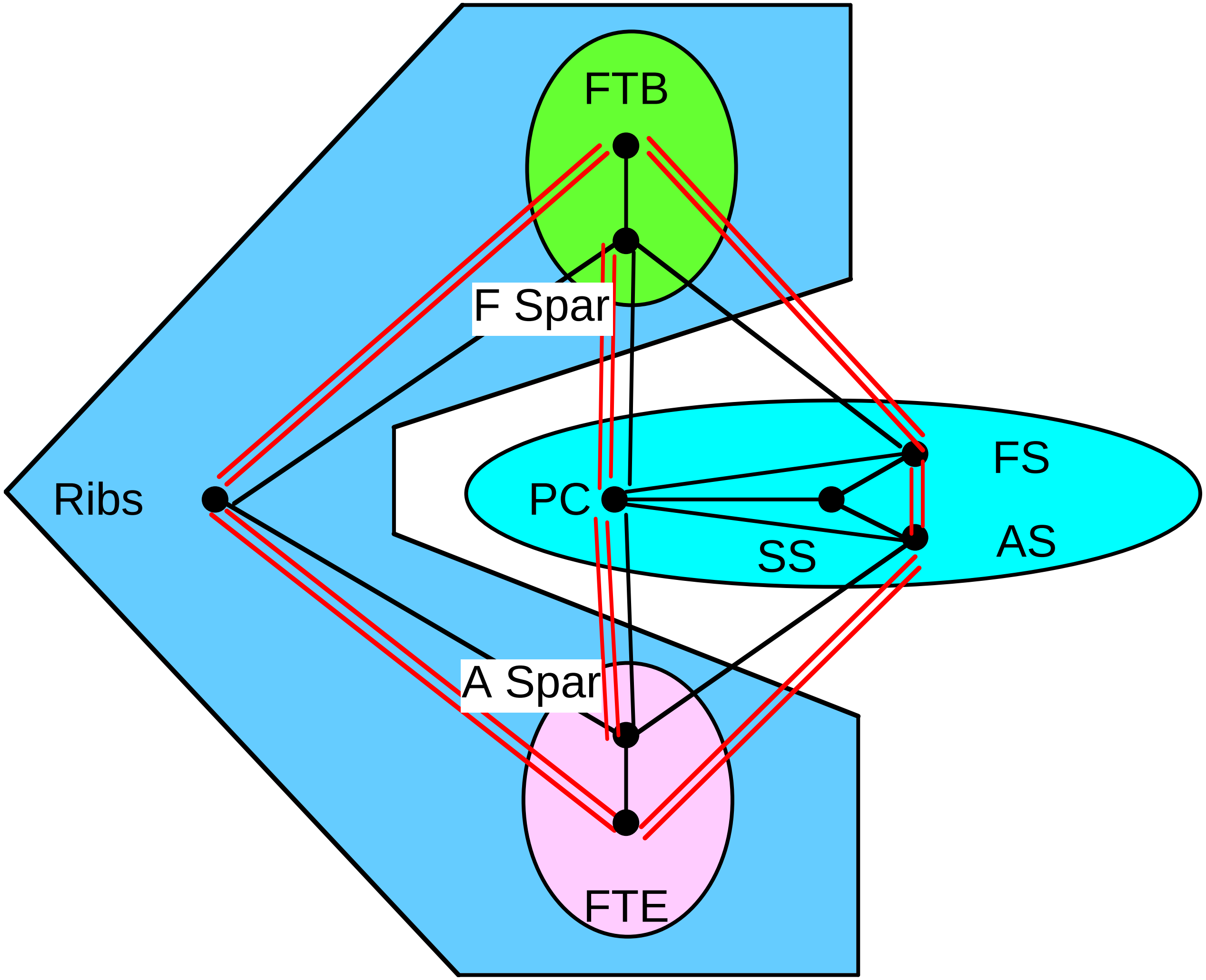
these subassemblies are impossible!

Assembly Access Problem Eliminates an Attractive Assembly Sequence

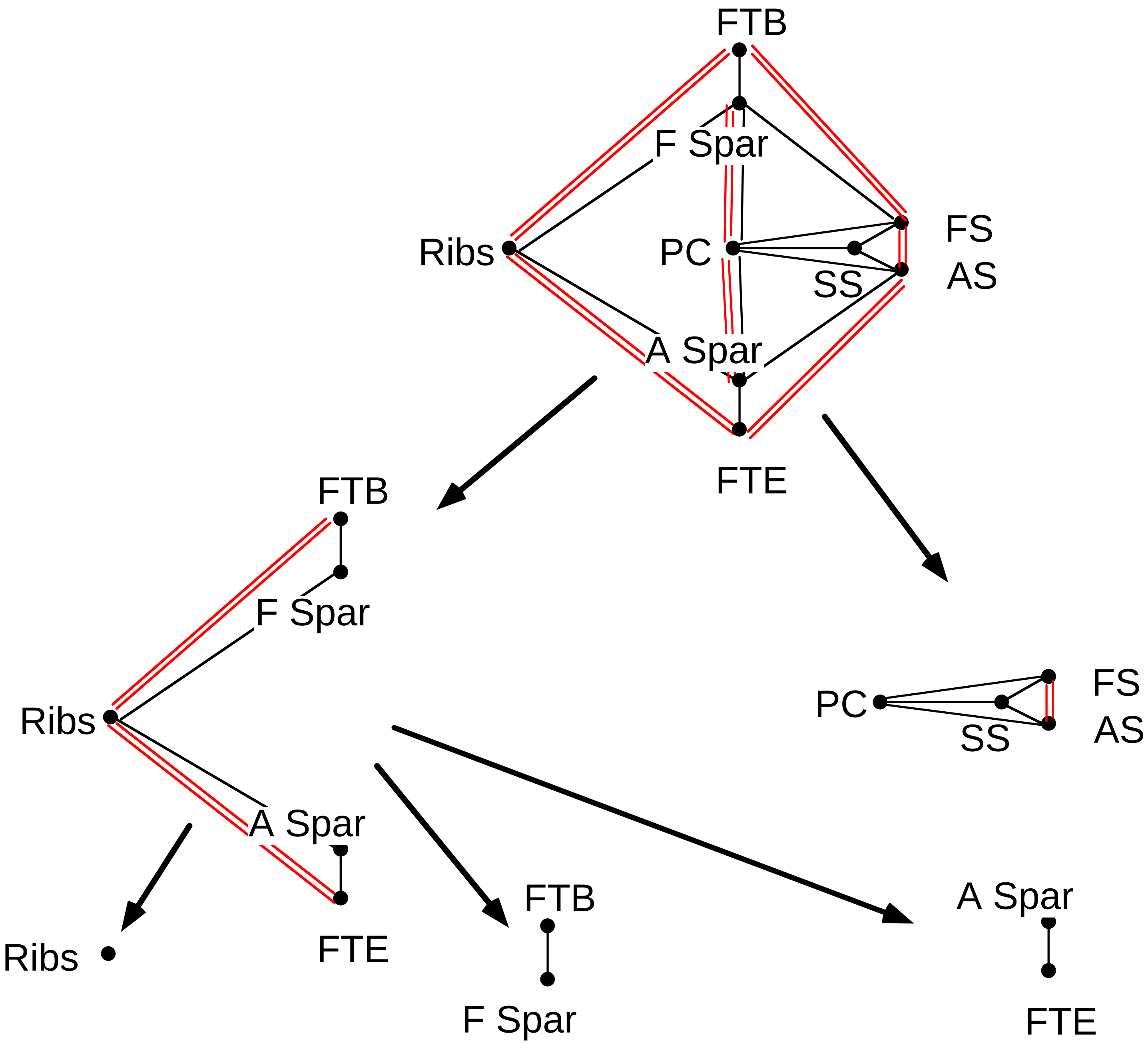


If plus chords are assembled to spar ends before skins are assembled to plus chords, then it will be almost impossible to join skins and stringers to plus chords

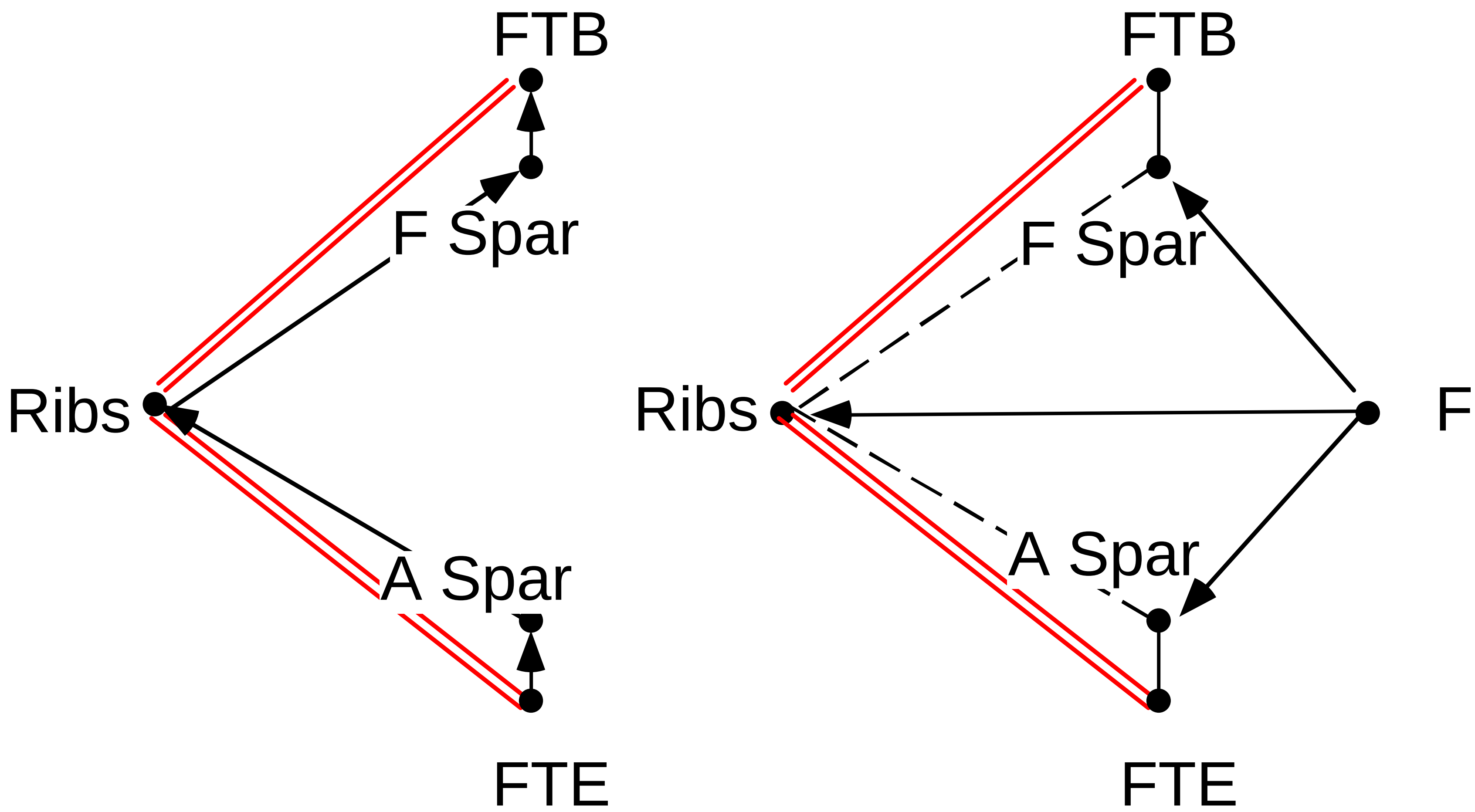
Actual Subassemblies



Actual Decomposition

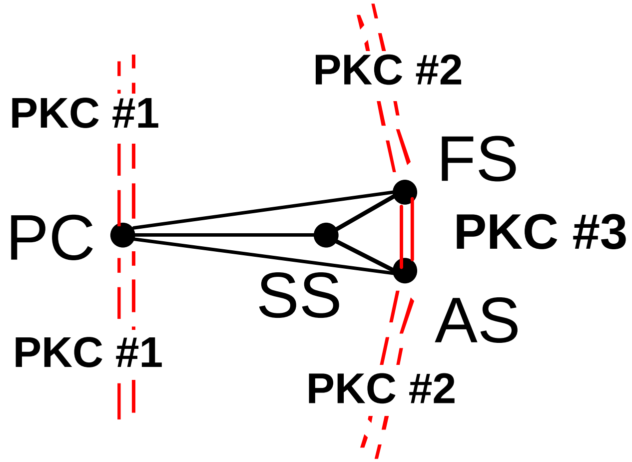


Type 1 and Type 2 Methods for One Subassembly - KC Flowdown Seems OK

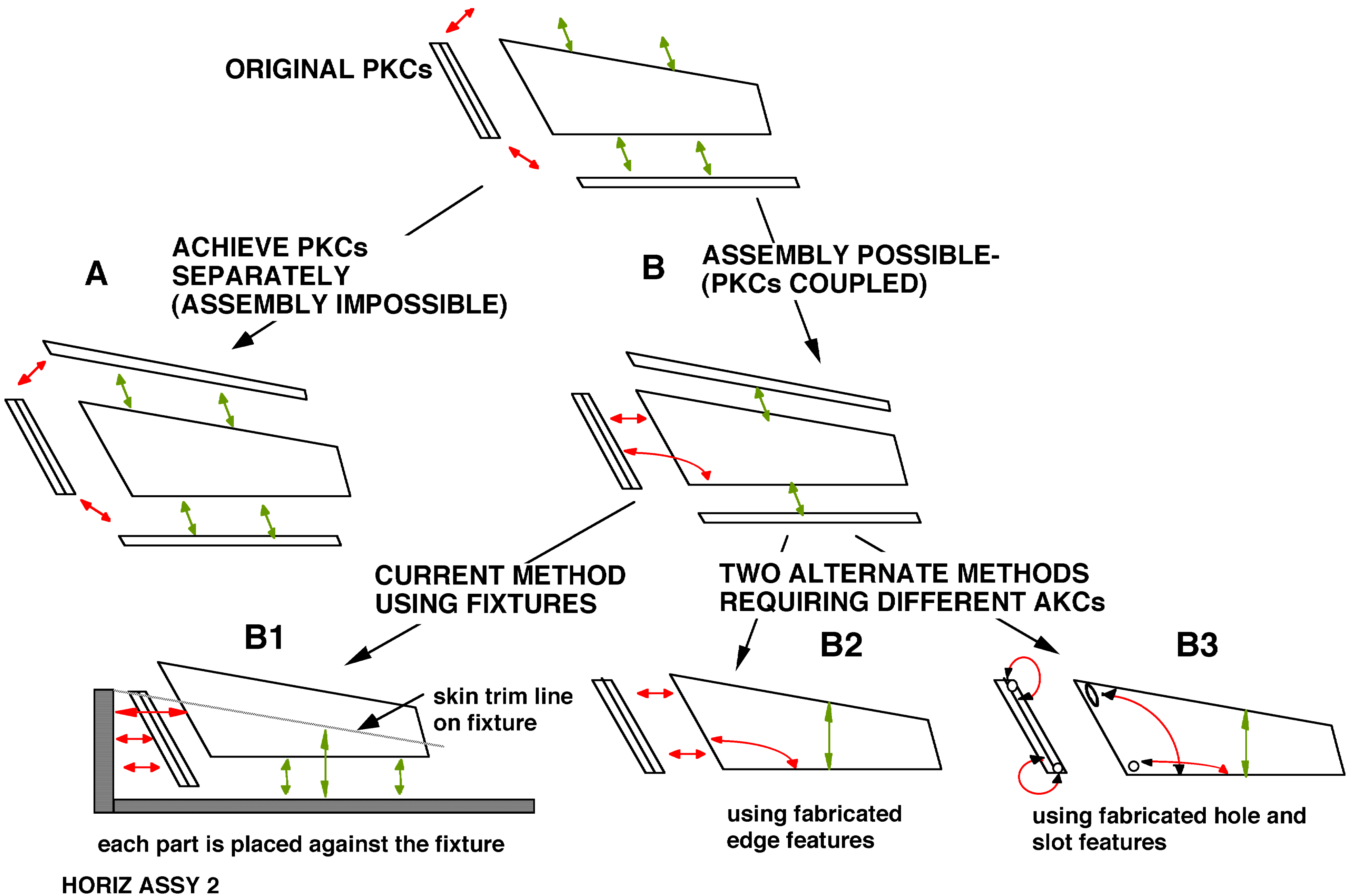


Second Subassembly Has Lost Its KC Links to Higher Level Assemblies

- Any assembly process for this subassembly must provide proxies for the missing KCs, regardless of whether the subassembly is made as a Type 1 or Type 2
- These KCs will be coupled
- Note that no drawing of this subassembly could be found



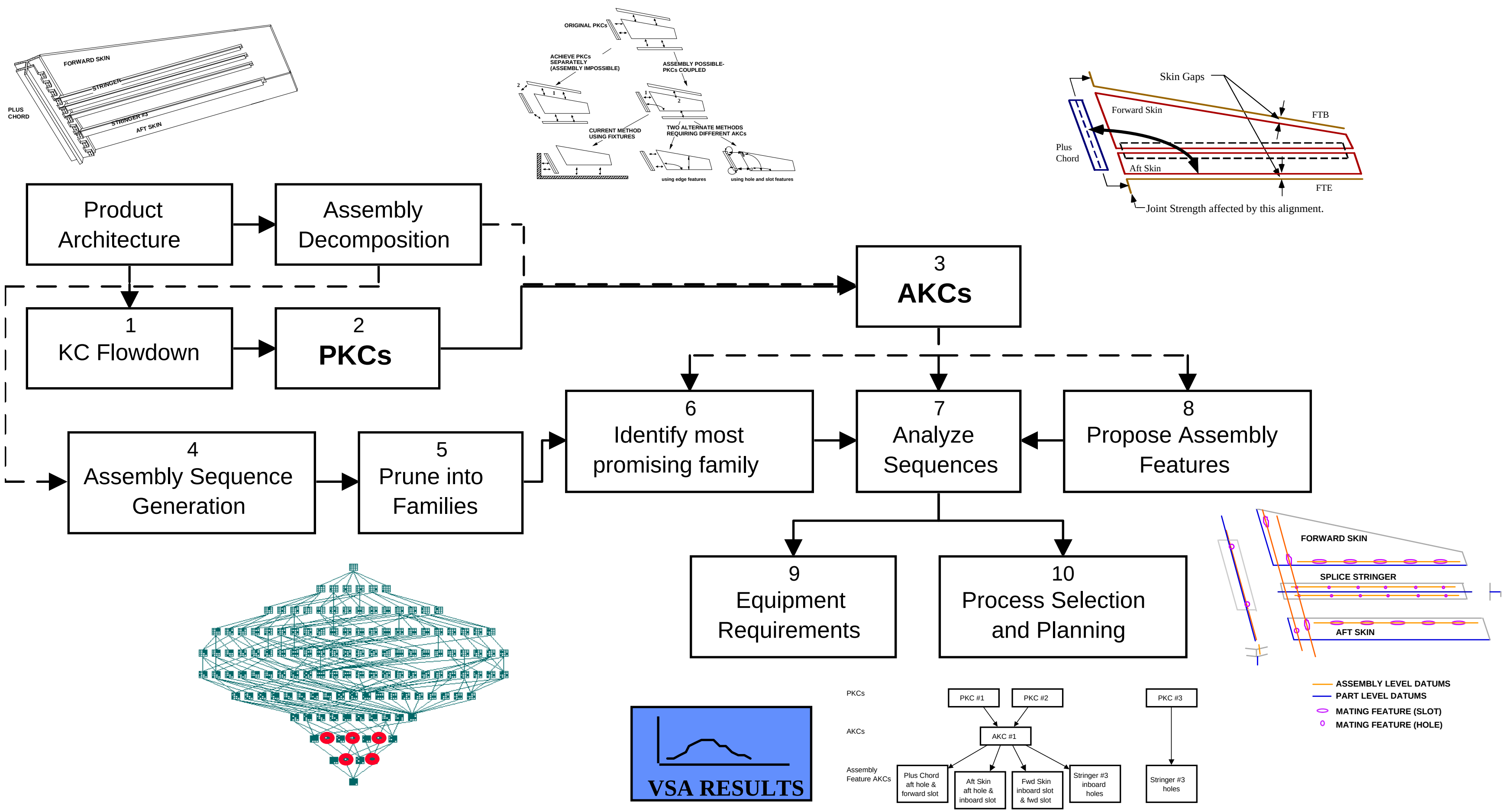
Possible Assembly Strategies



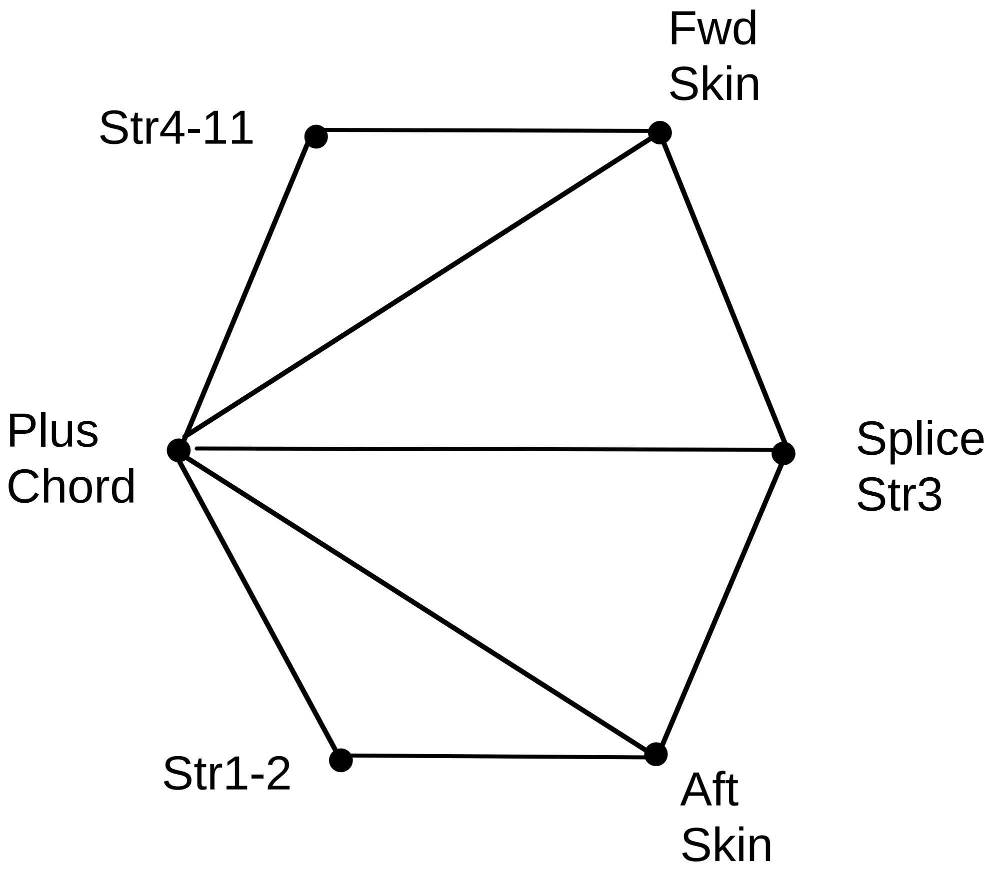
Our Challenge

- Current assembly method relies on costly fixtures
- Can a process be devised that does not rely on fixtures other than for support against gravity?
- Can such a process achieve the PKCs?
- Would it be economical?
- What new worker skills would be needed?
- Can we figure out what the old process was doing so we can reproduce its objectives using new methods?

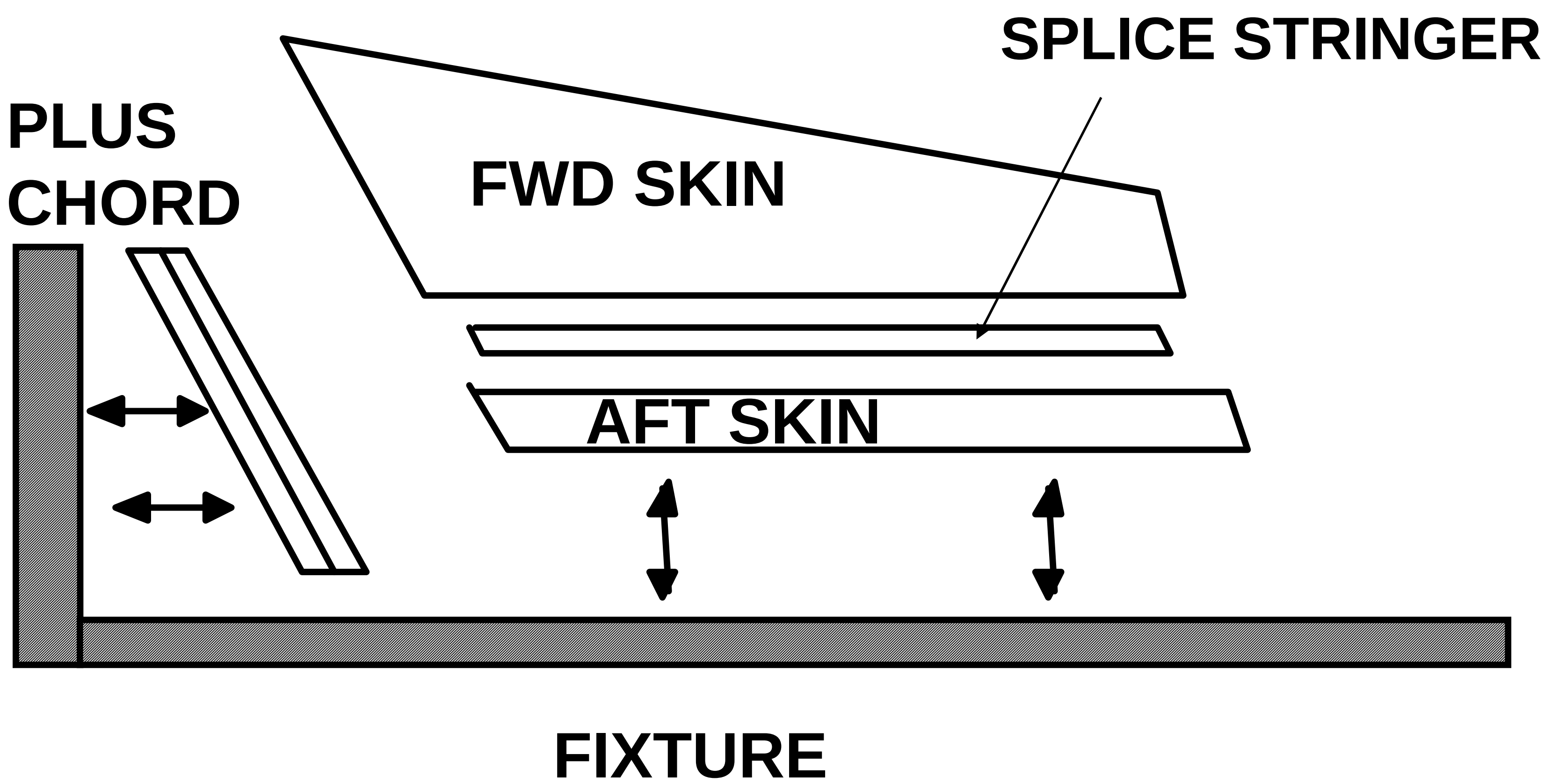
Diagram of Assembly Analysis Process



Liaison Diagram

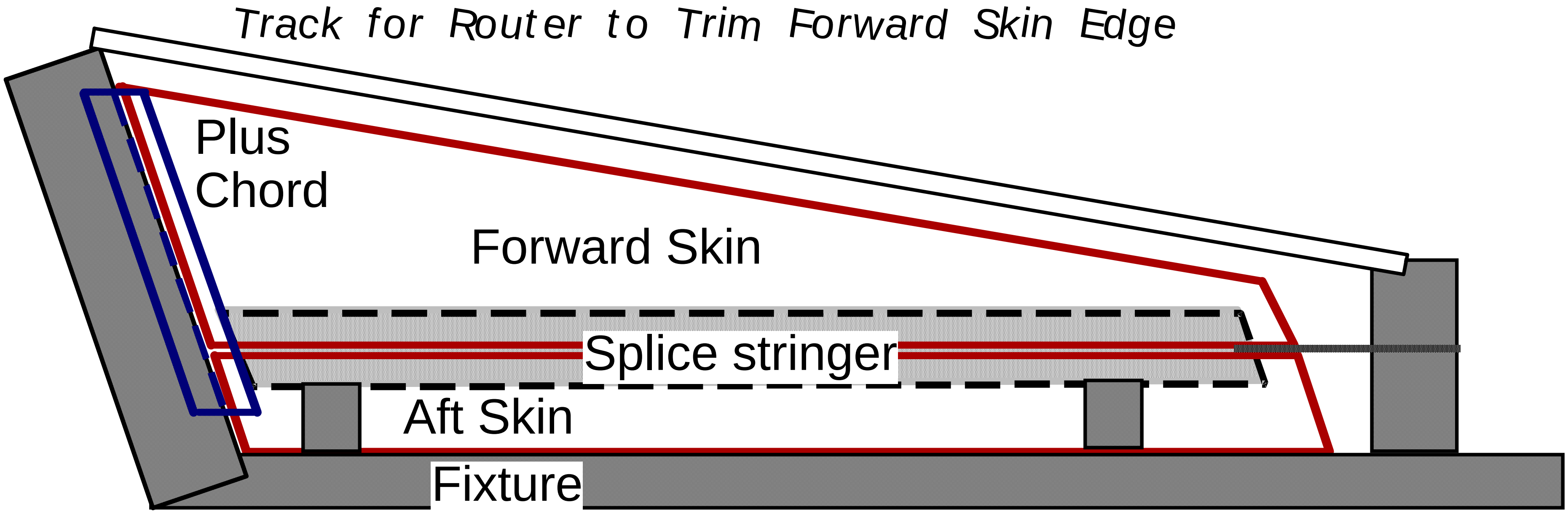


Current Skin Assembly Process

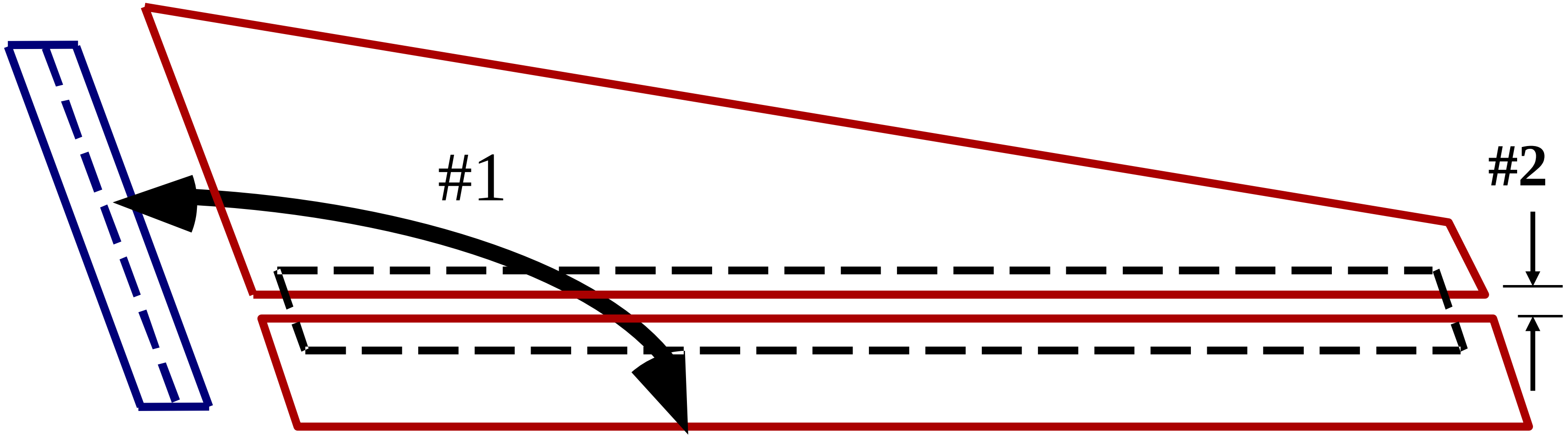


Everything indexes off the fixture

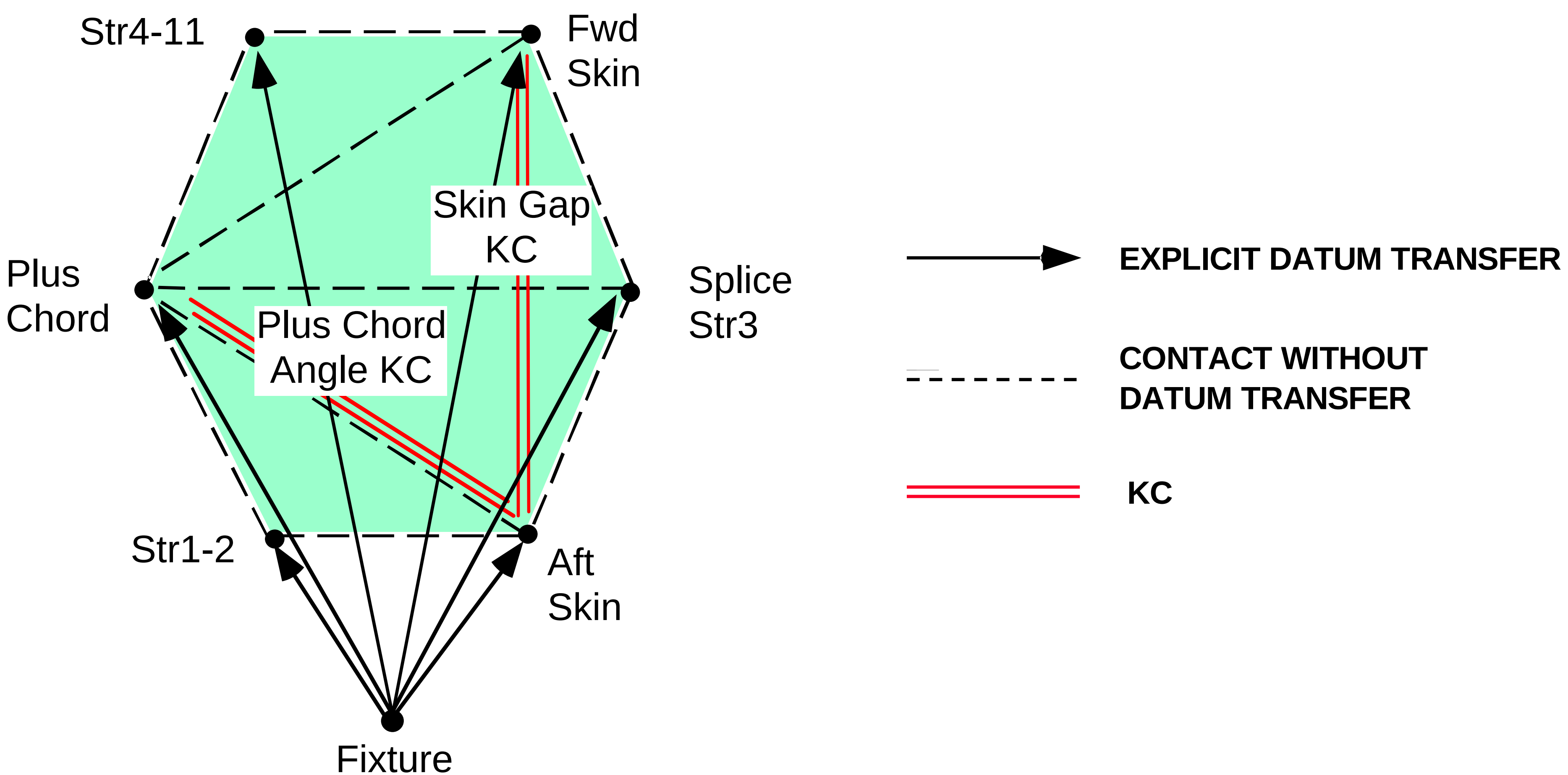
Current Skin Assembly Process - 2



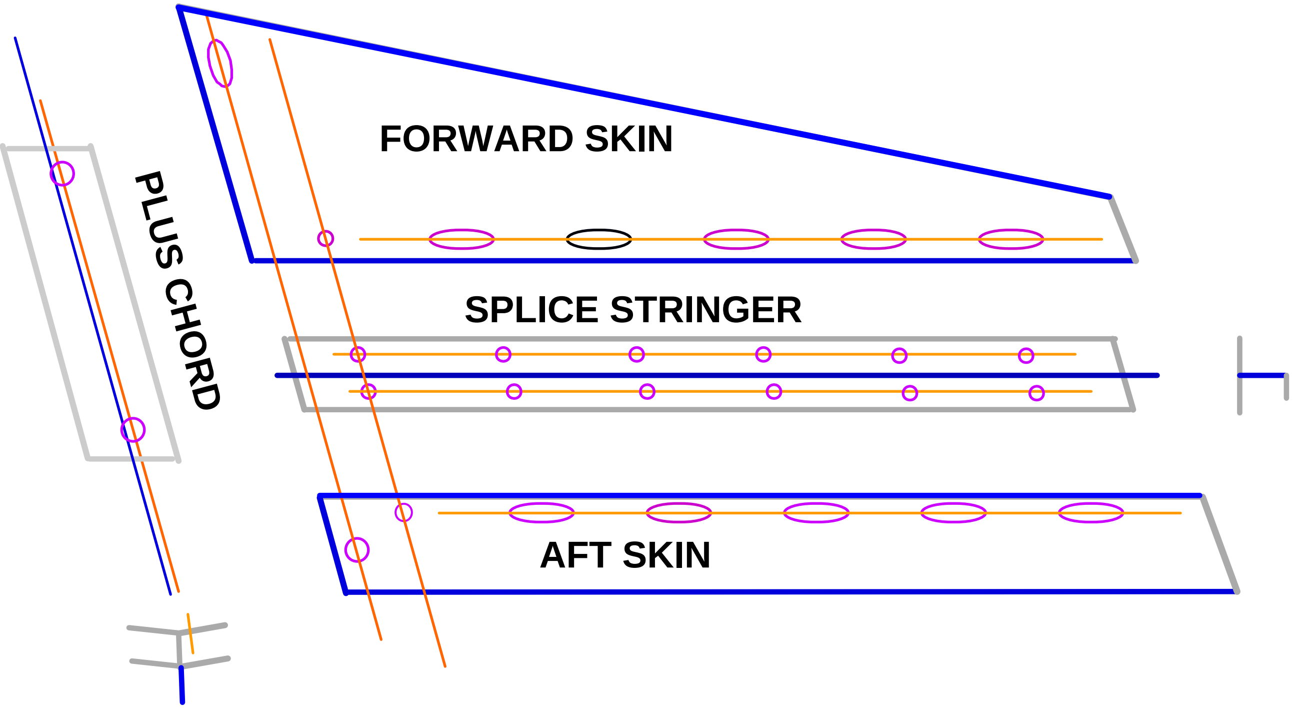
Assembly KC #1 & #2



Datum Flow Chain for Current Skin Process

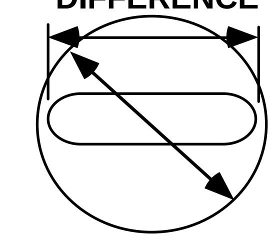


New Process #1: Fixtureless (Type 1)

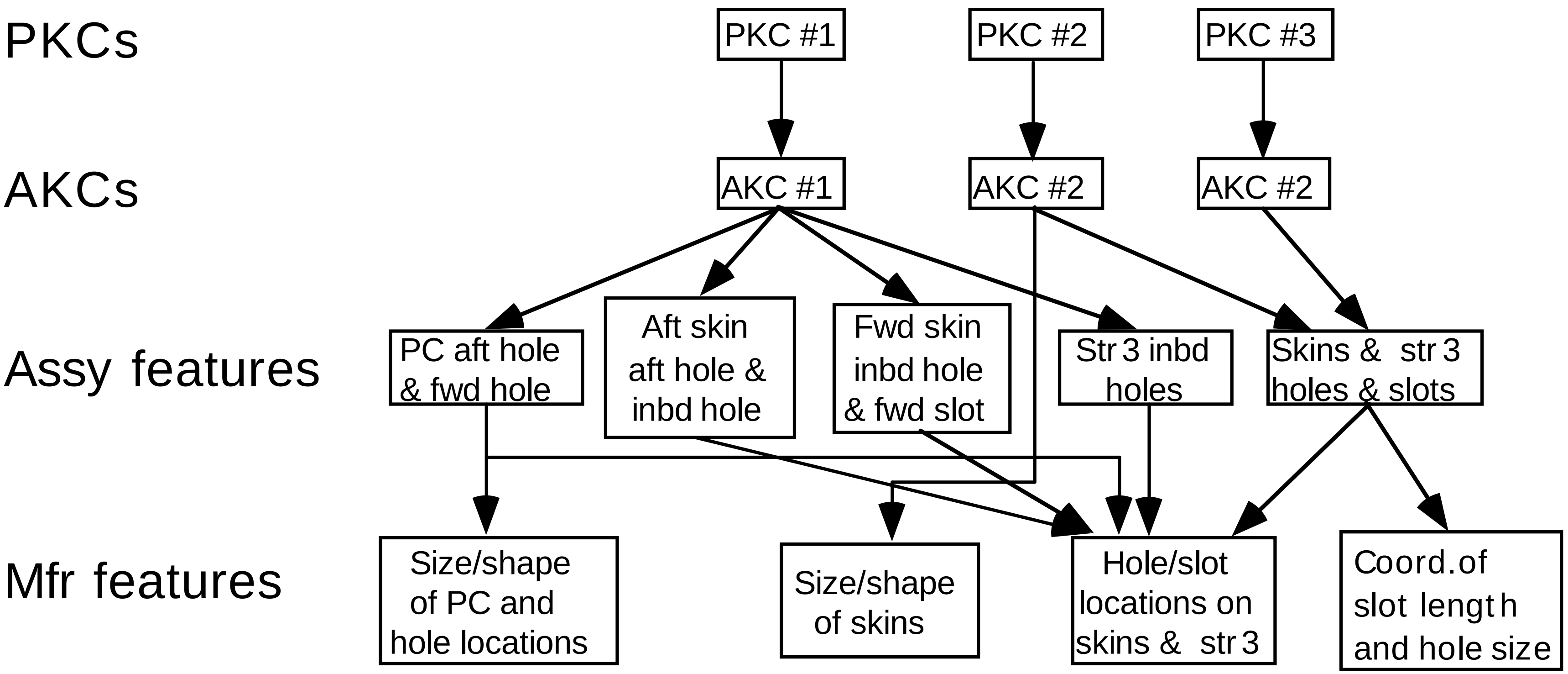


HOLES CHOSEN FOR LOCATION
SLOTS CHOSEN FOR LOCATION, THERMAL & SHOT PEEN GROWTH ACCOMMODATION
ALL SLOTS DRILLED OUT TO FULL SIZE HOLES AT FINAL ASSEMBLY

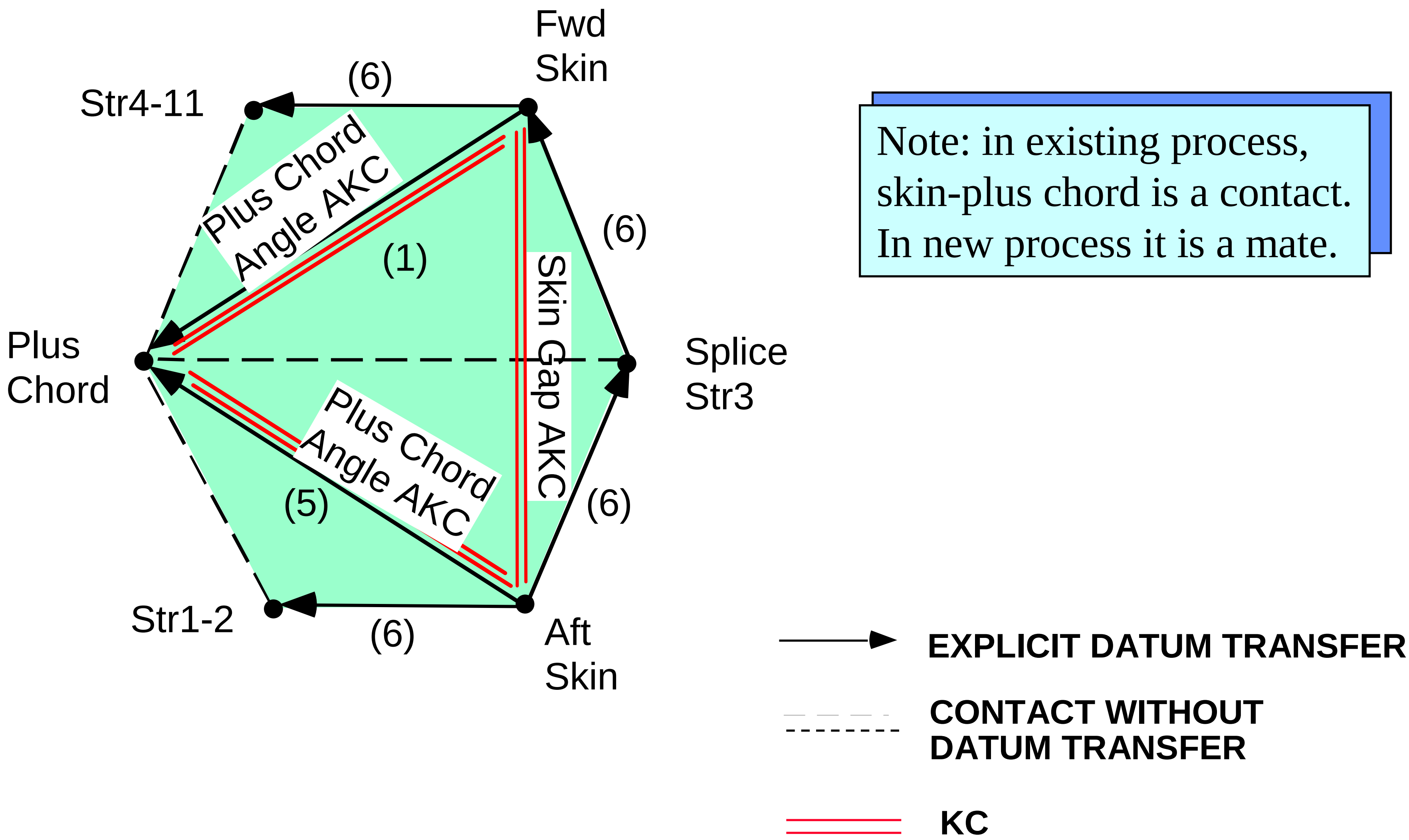
- ASSEMBLY LEVEL DATUMS
- PART LEVEL DATUMS
- MATING FEATURE (SLOT)
- MATING FEATURE (HOLE)



PKC Delivery Map for New Process #1

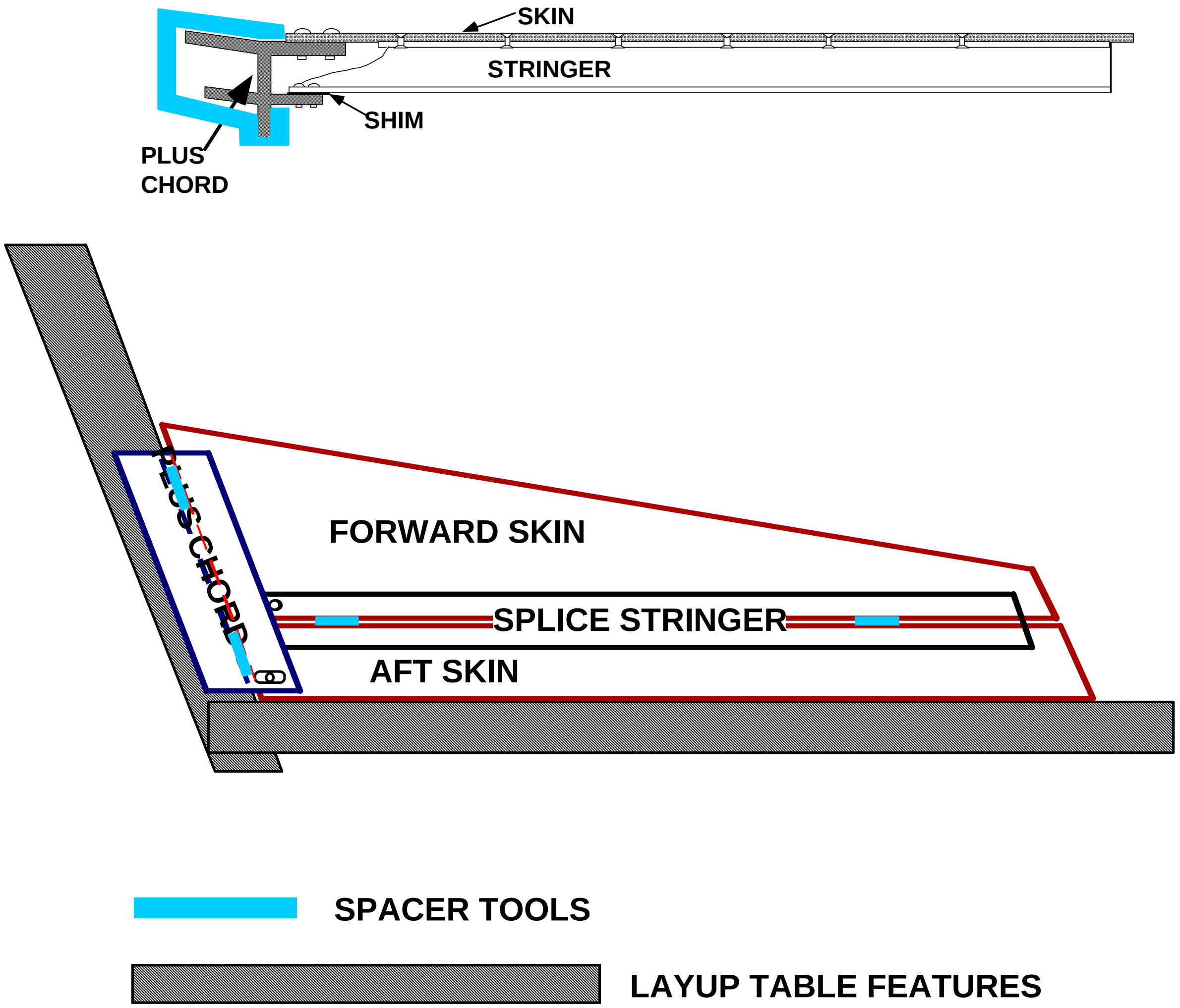


Datum Flow Chain for New Process #1

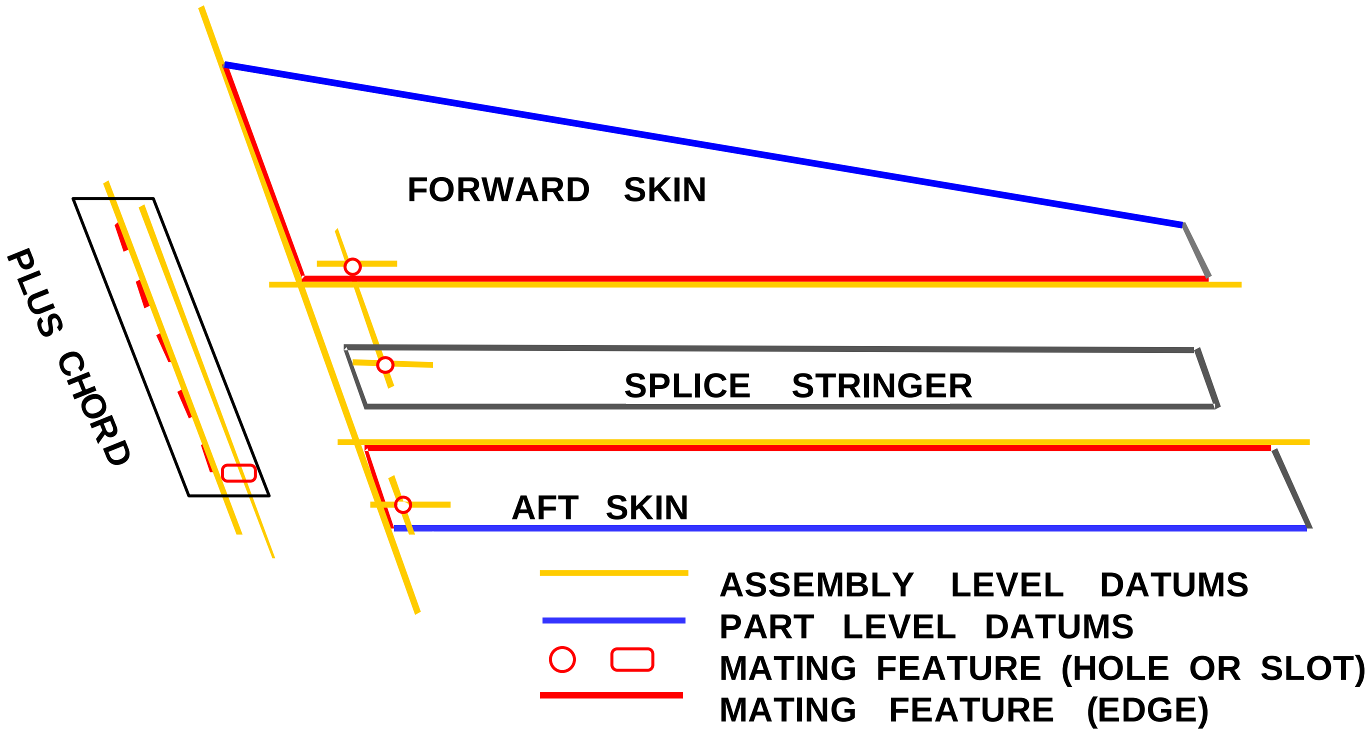


Note: in existing process, skin-plus chord is a contact. In new process it is a mate.

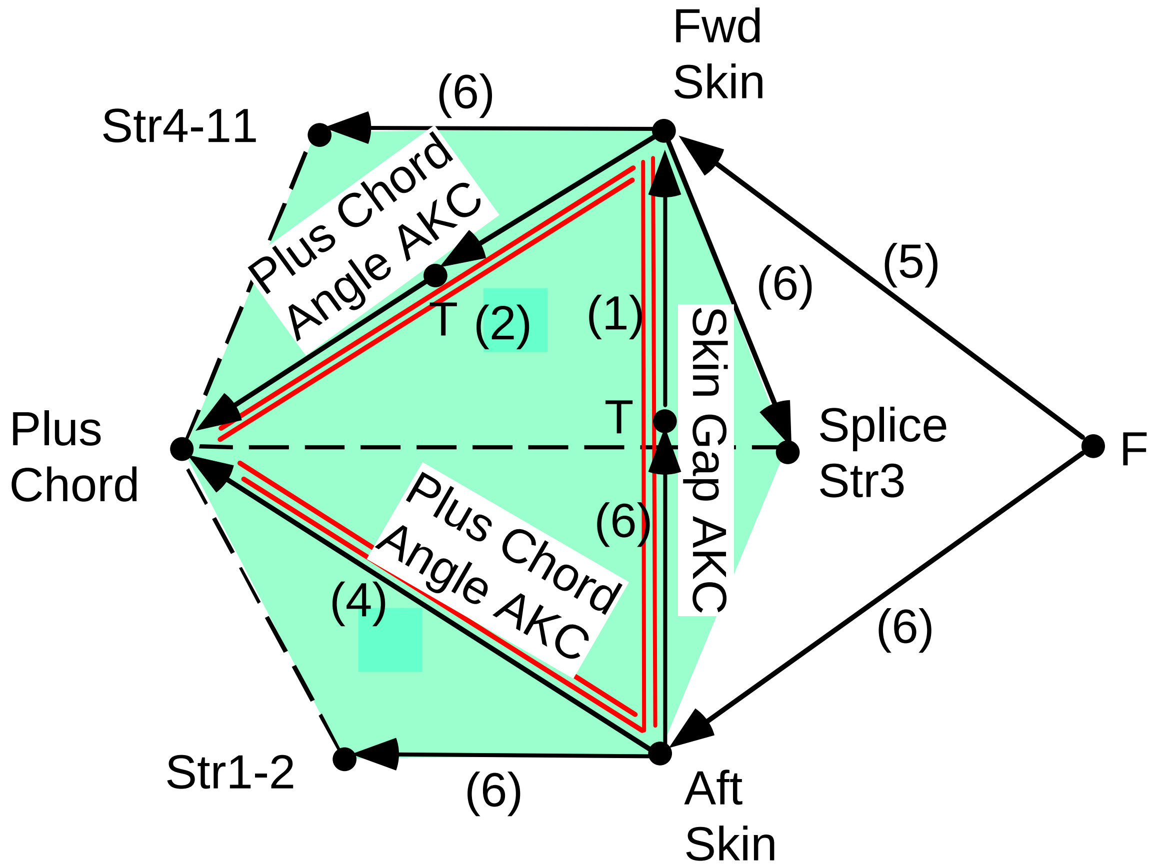
New Process #2



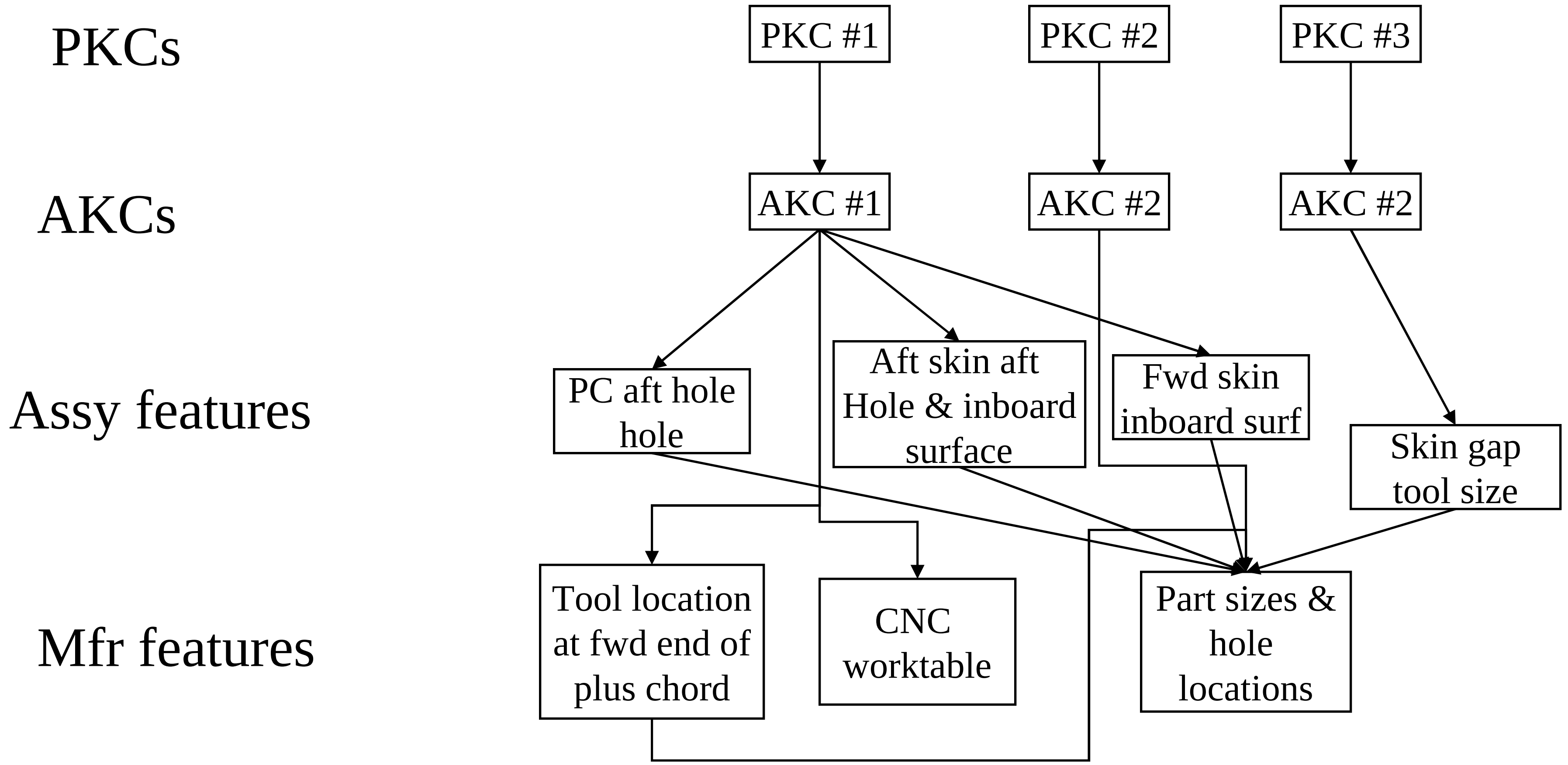
Assembly Features for Process #2



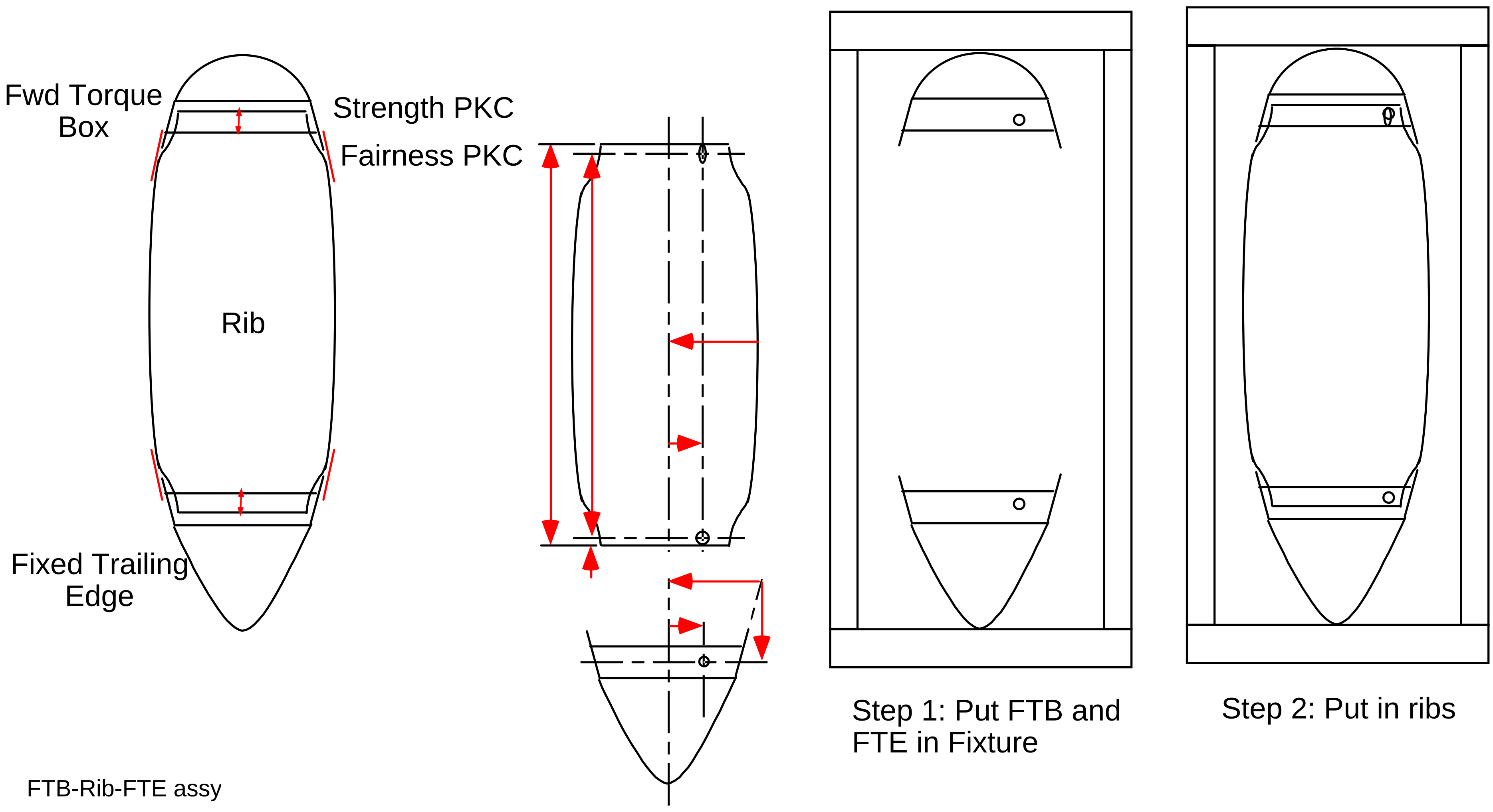
Datum Flow Chain for New Process #2



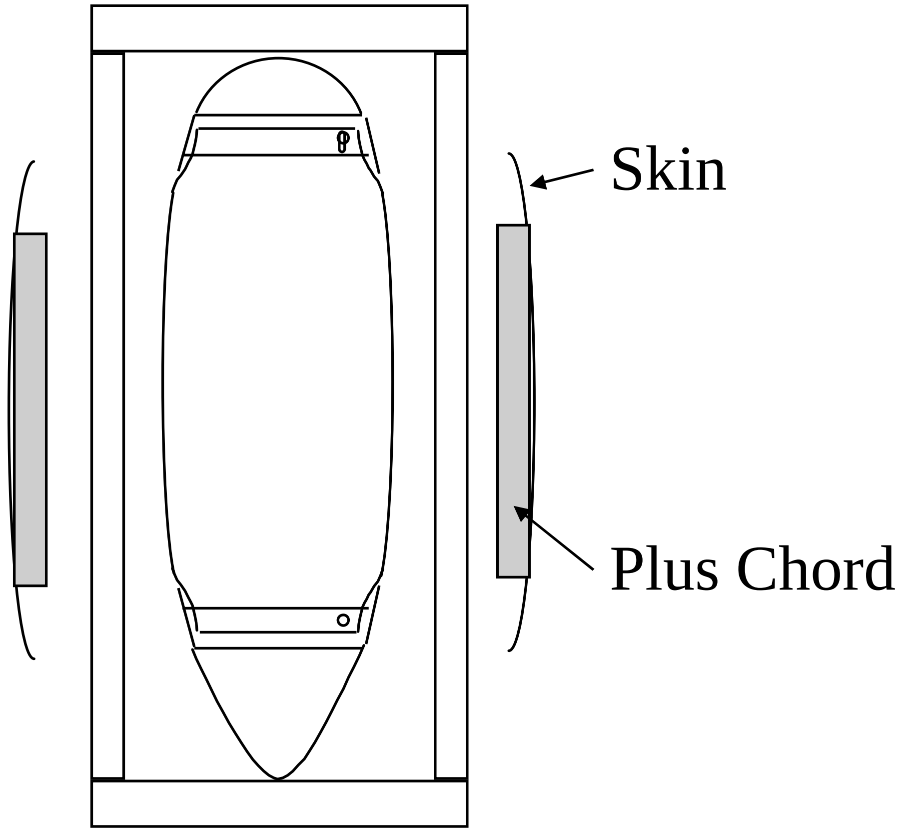
KC Deliverability Map - Process #2



Rib-Spar as a Type 2 Assembly

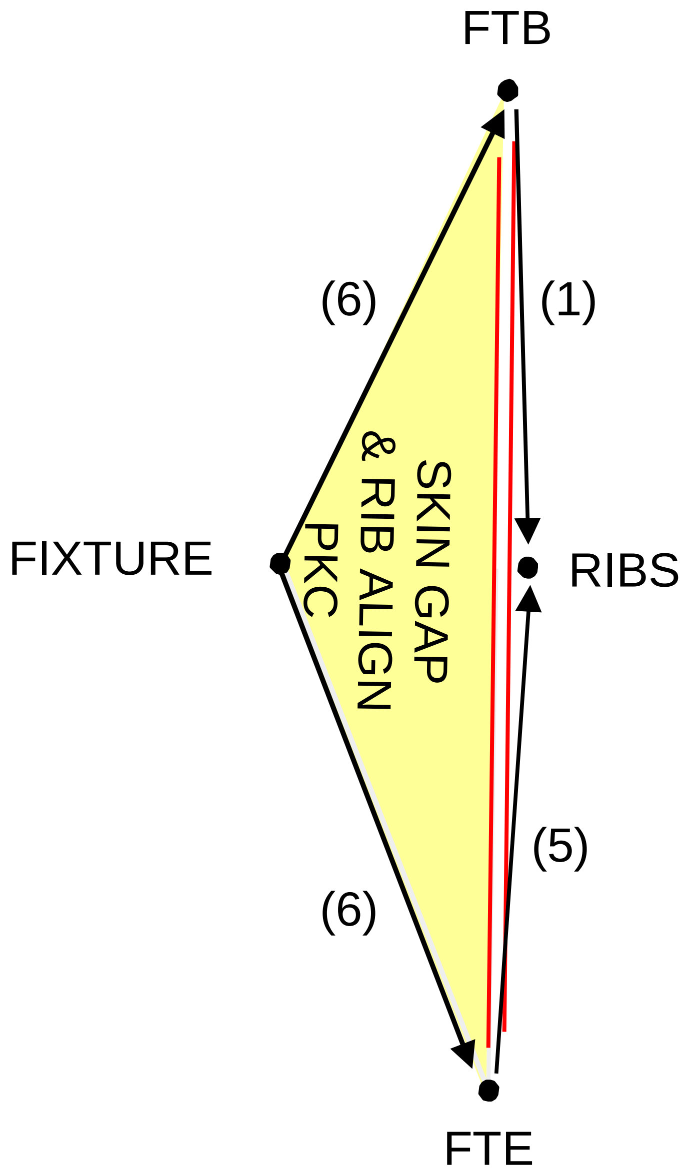


Rib-Spar Assembly - 2

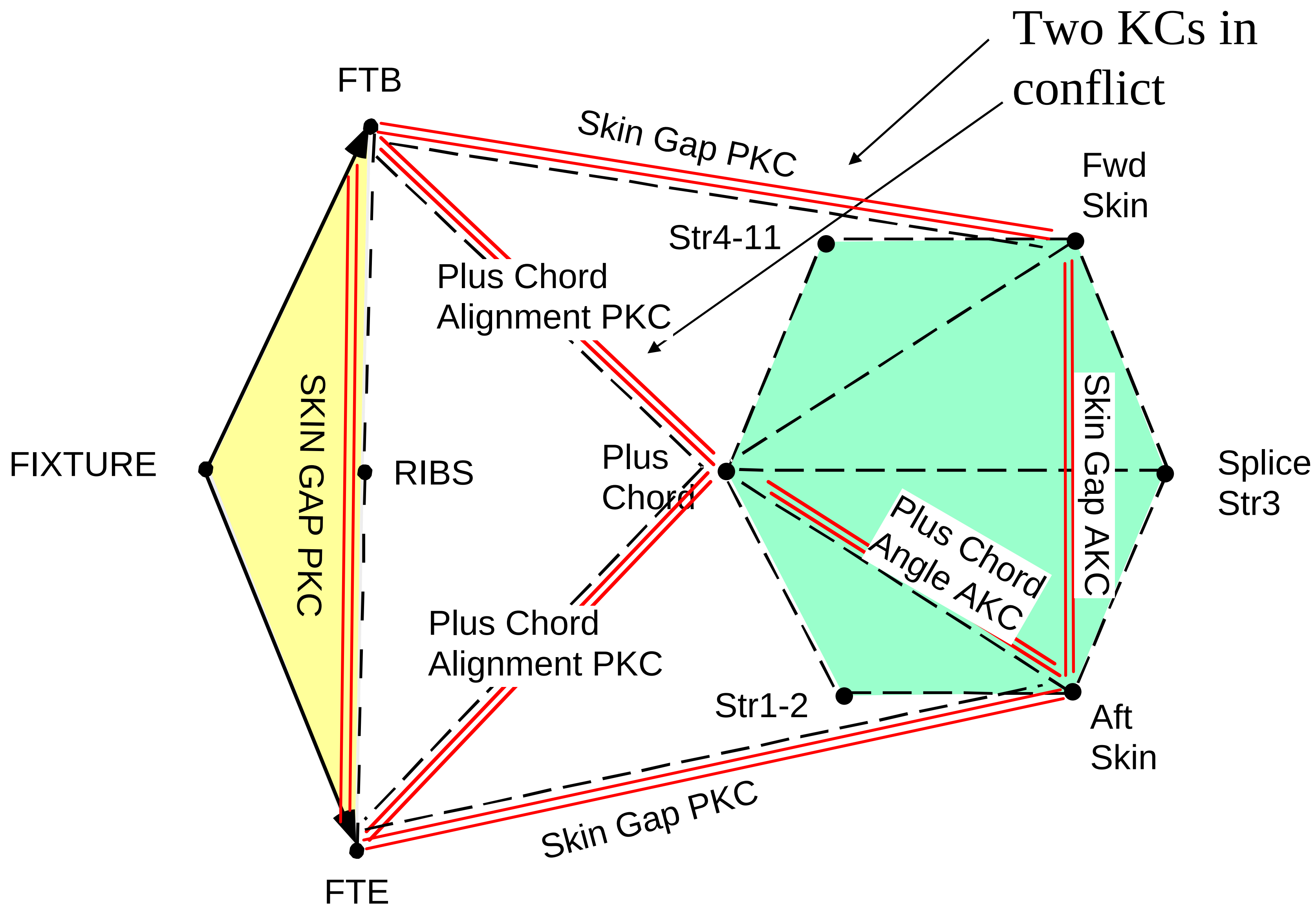


Step 3: Add skins and adjust skin gaps and plus chord alignment to FTB and FTE

DFC for Rib-Spar as a Type-2



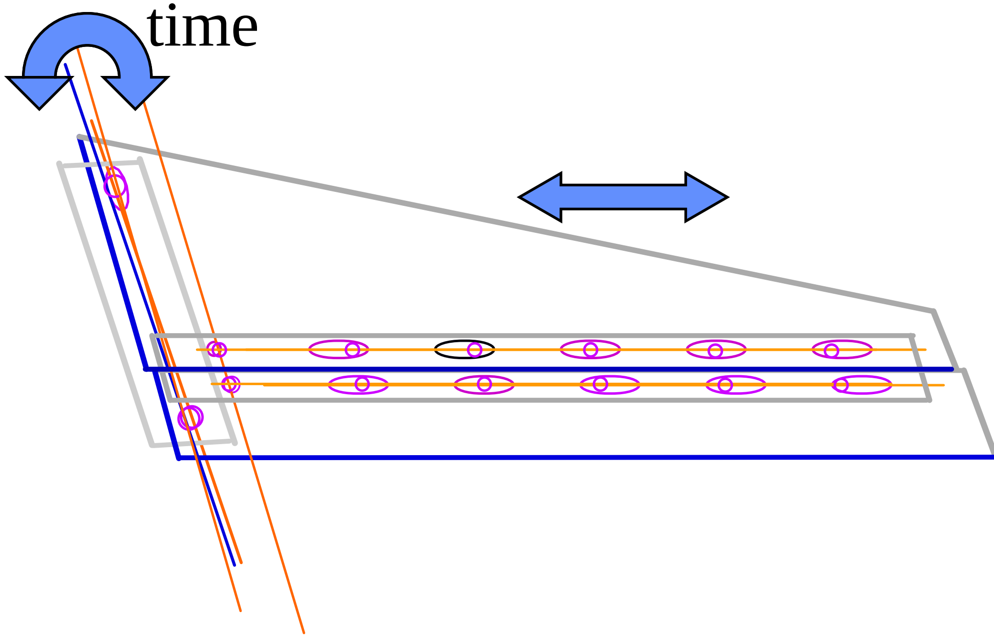
DFC for Wing Assembly as a Type 2



Tolerance Analysis of KC Delivery Using VSA

- VSA was used to on each candidate new process
- Results show that process 1 is unable to deliver AKC & PKC 1 all the time because the holes in the splice stringer can't be placed accurately enough
- This also hurts PKC 2 and 3

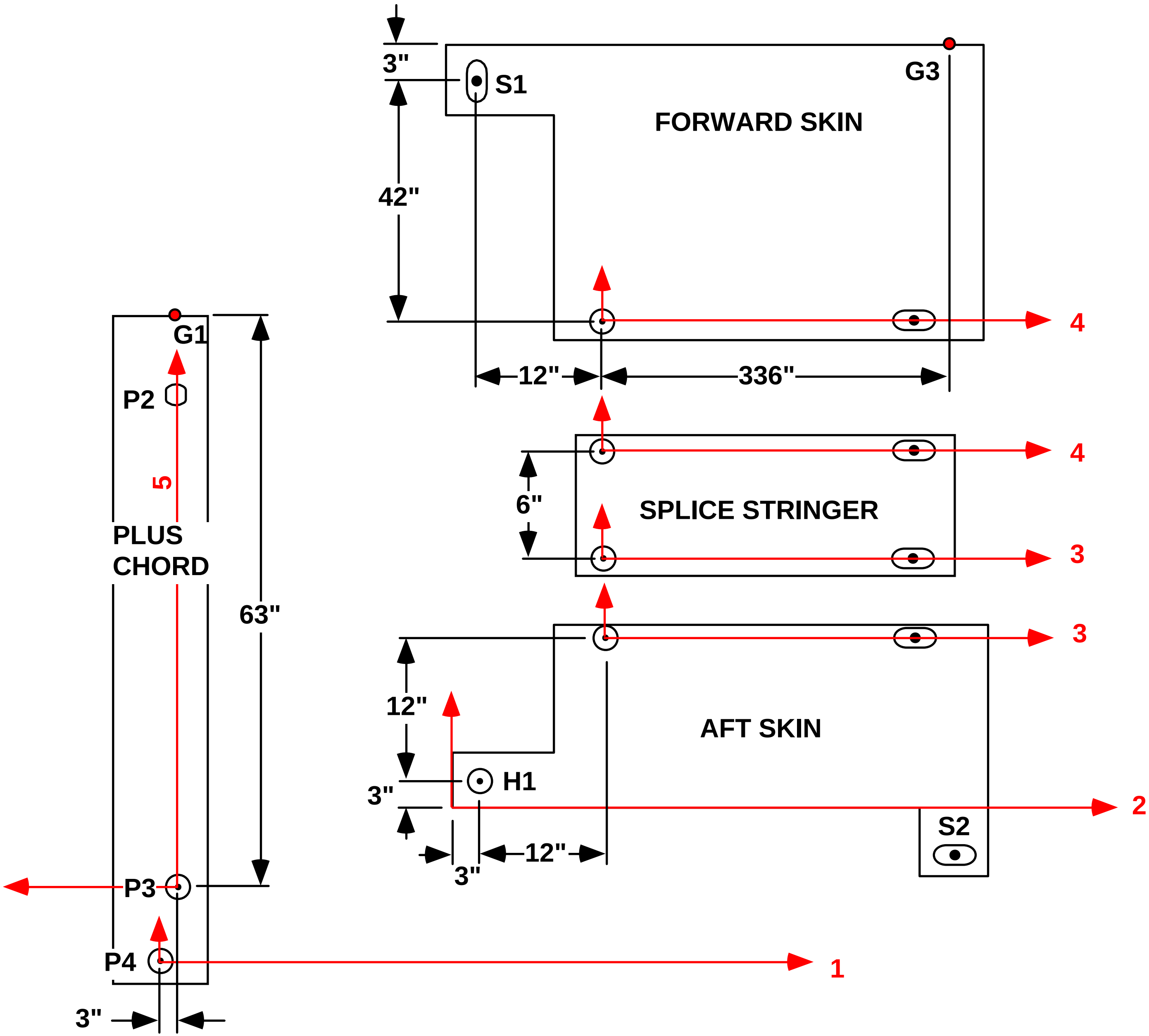
- Process 2 is able to deliver all 3 PKCs 100% of the time



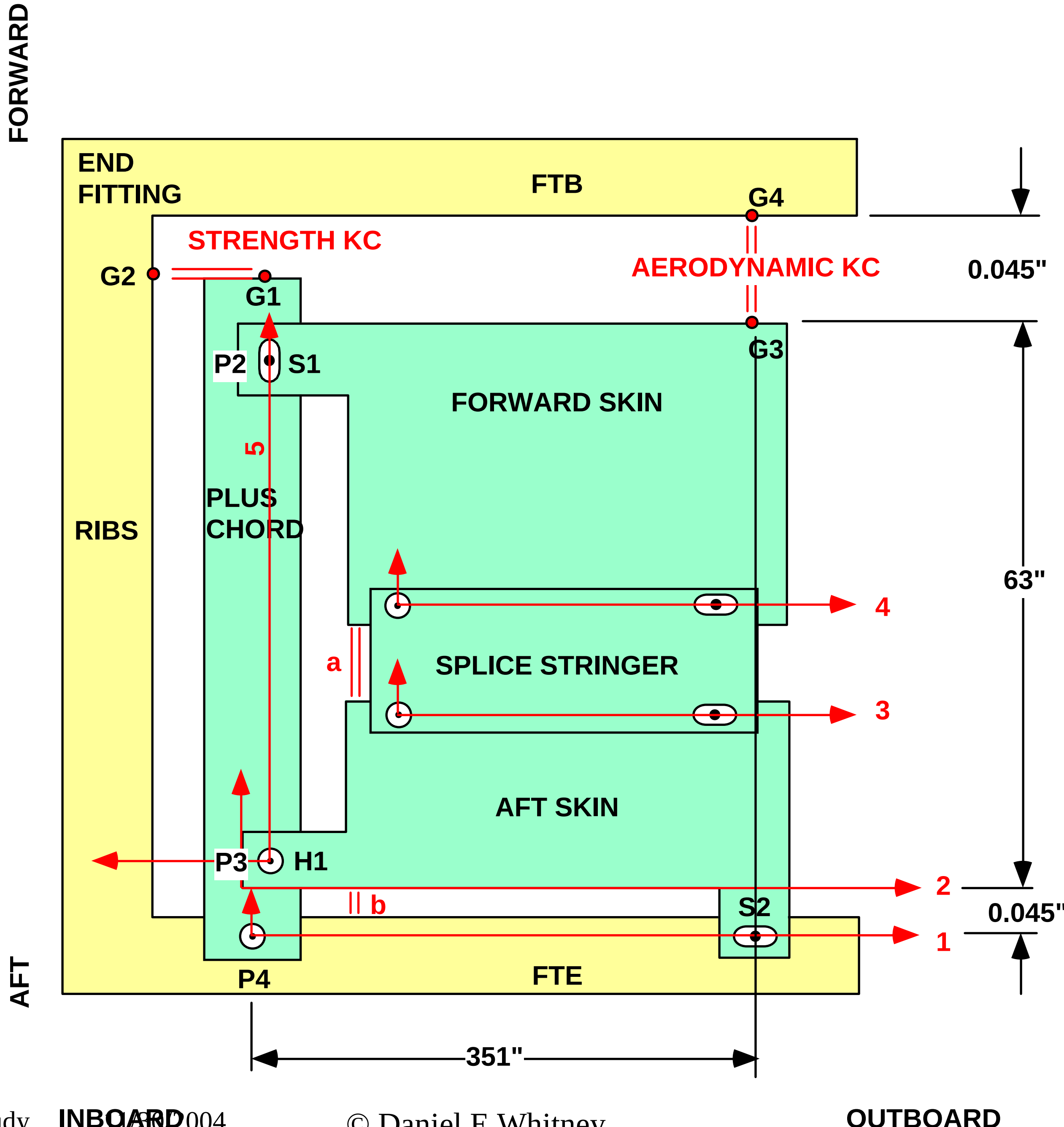
Matlab(TM) Analysis

- Assumed assemblers could maneuver the wing skin laterally and angularly
- Assumed smaller variation in hole and slot placement
- Assumed that the rest of the wing was error-free
- Determined that only a few assemblies would fail

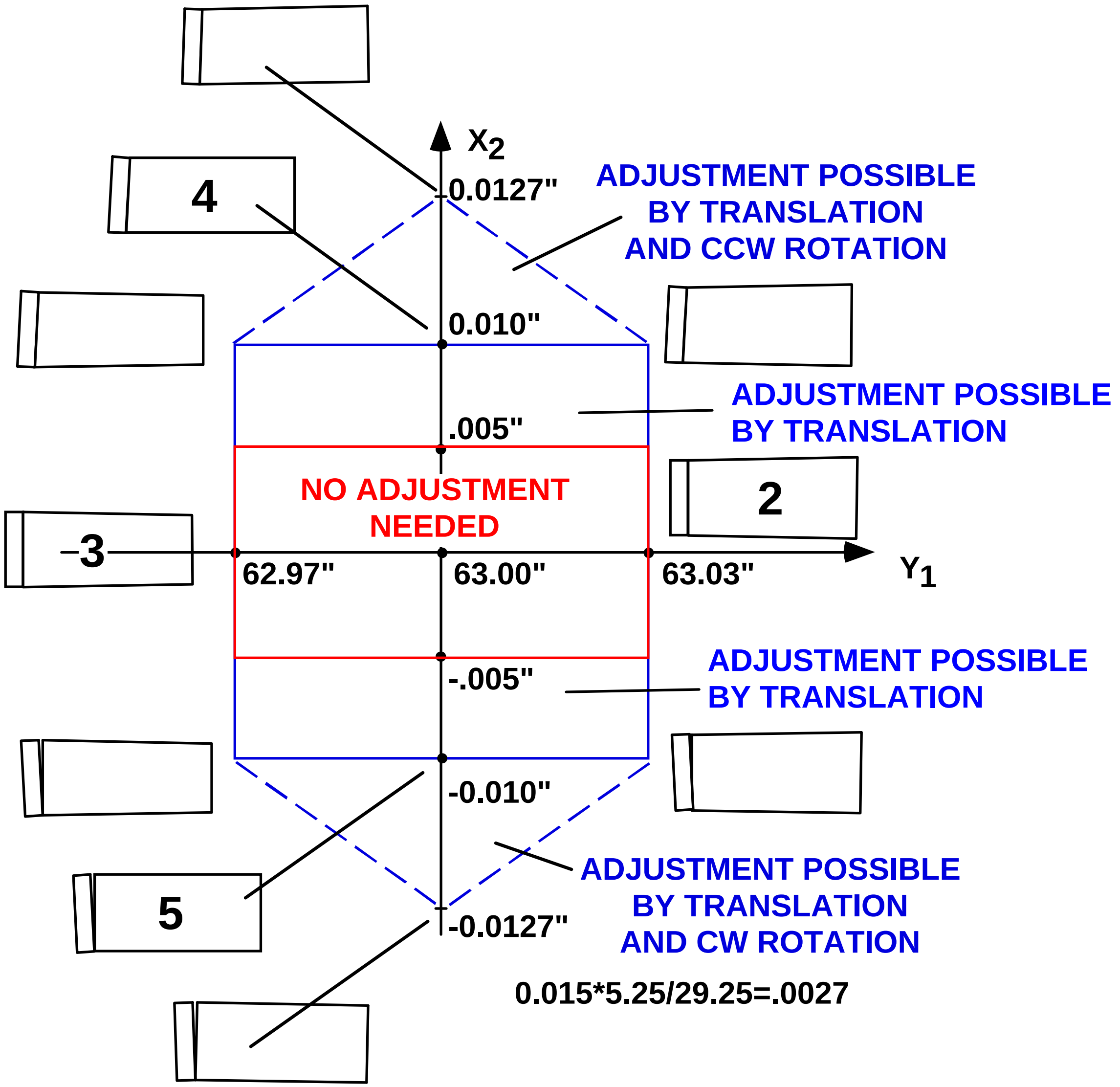
Parts and Their Frames



Parts Assembled and Frames Aligned

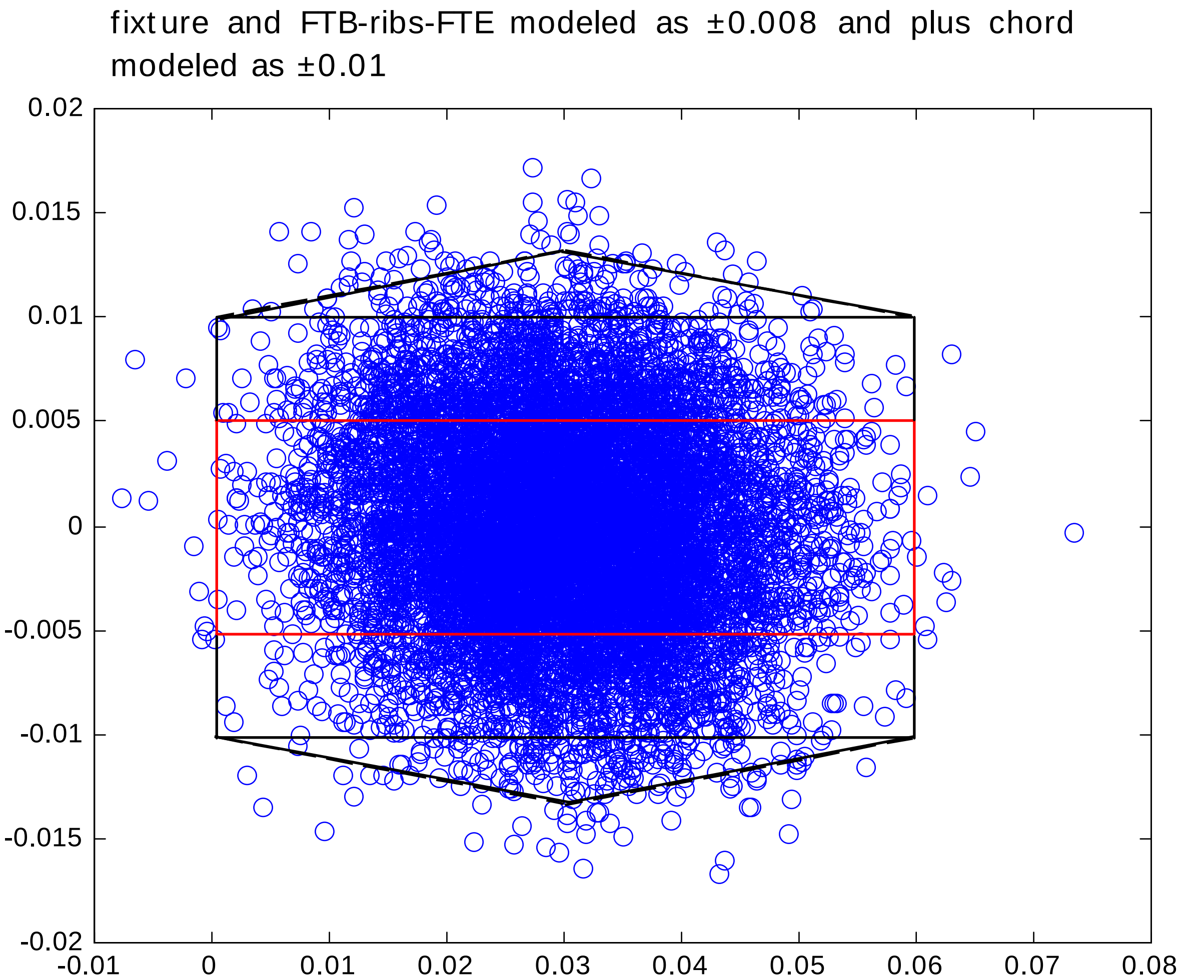


Sample Space for Tolerance Analysis



Matlab(TM) Results

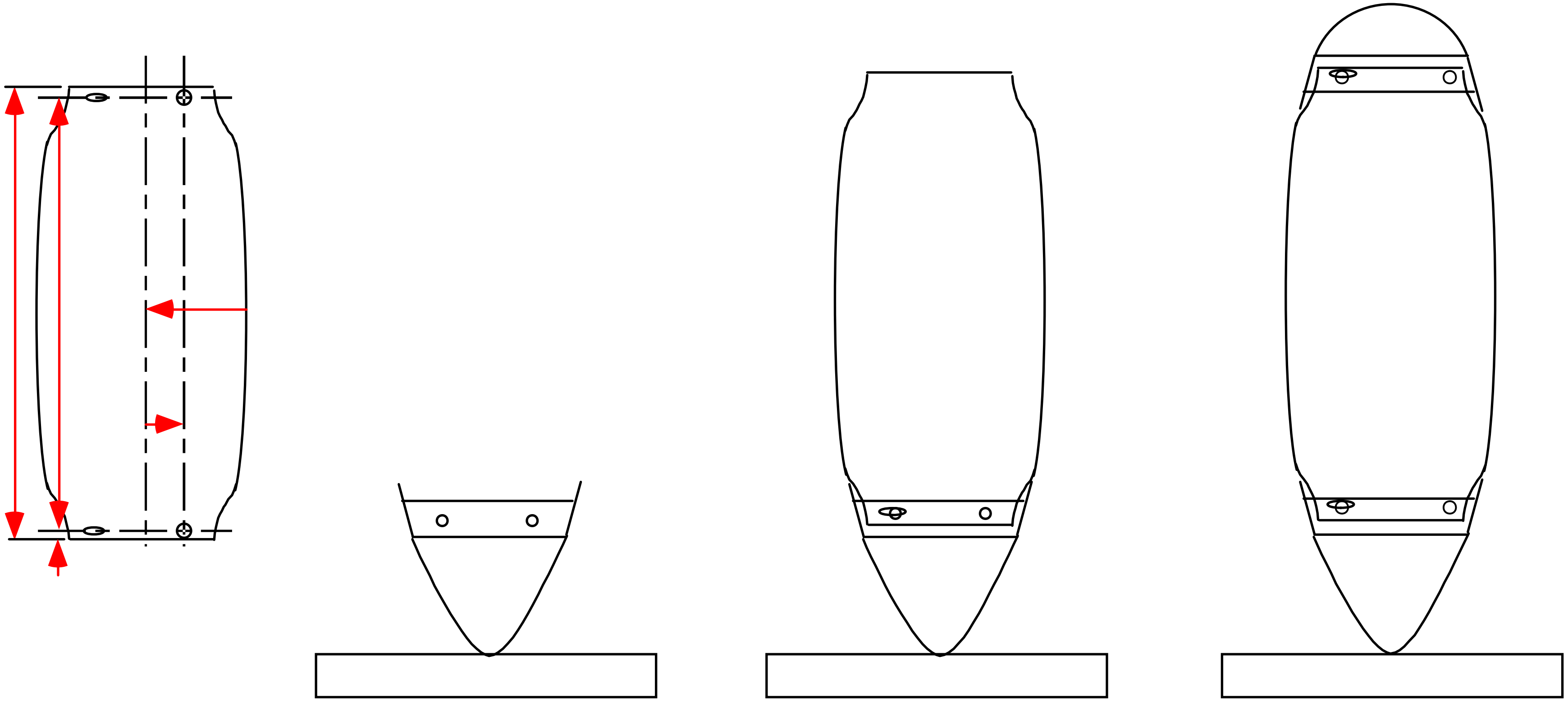
~120 out of 10000 fall outside



Pros & Cons of Proposed Processes

	Current Process	Proposed Process #1	Proposed Process #2
Pros	• Delivers all AKCs and PKCs repeatably	• Delivers AKC #2 and PKC #3 repeatably • Completely flexible method • No dedicated fixtures • Uses existing fab equipment • Least costly • Controls critical interfaces	• Delivers all AKCs and PKCs repeatably • Completely flexible method • Uses existing fab equipment • Controls critical interfaces
Cons	• Inflexible fixtures • Variation absorbed at stringer-plus chord interface	• Fails to deliver AKC #1 on a few assemblies • PKC #1 & #2 not delivered on those same assembies	• Requires higher-functionality tack fixture (higher cost) • Requires a limited number of small fixtures

Rib-Spar as a Type 1 Assembly



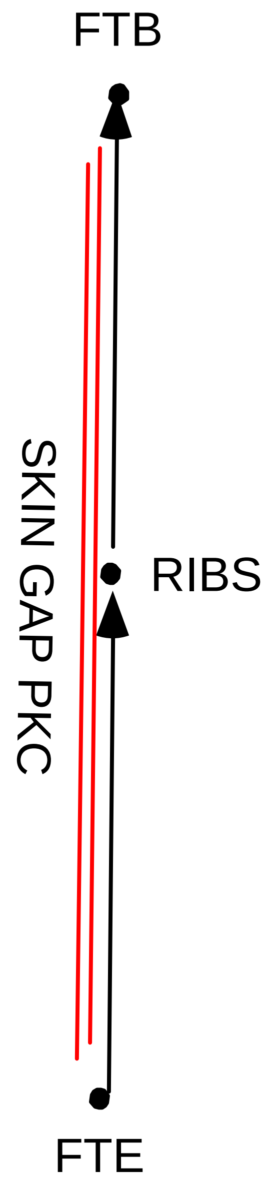
Step 1: Put FTE on Support

Step 2: Add ribs

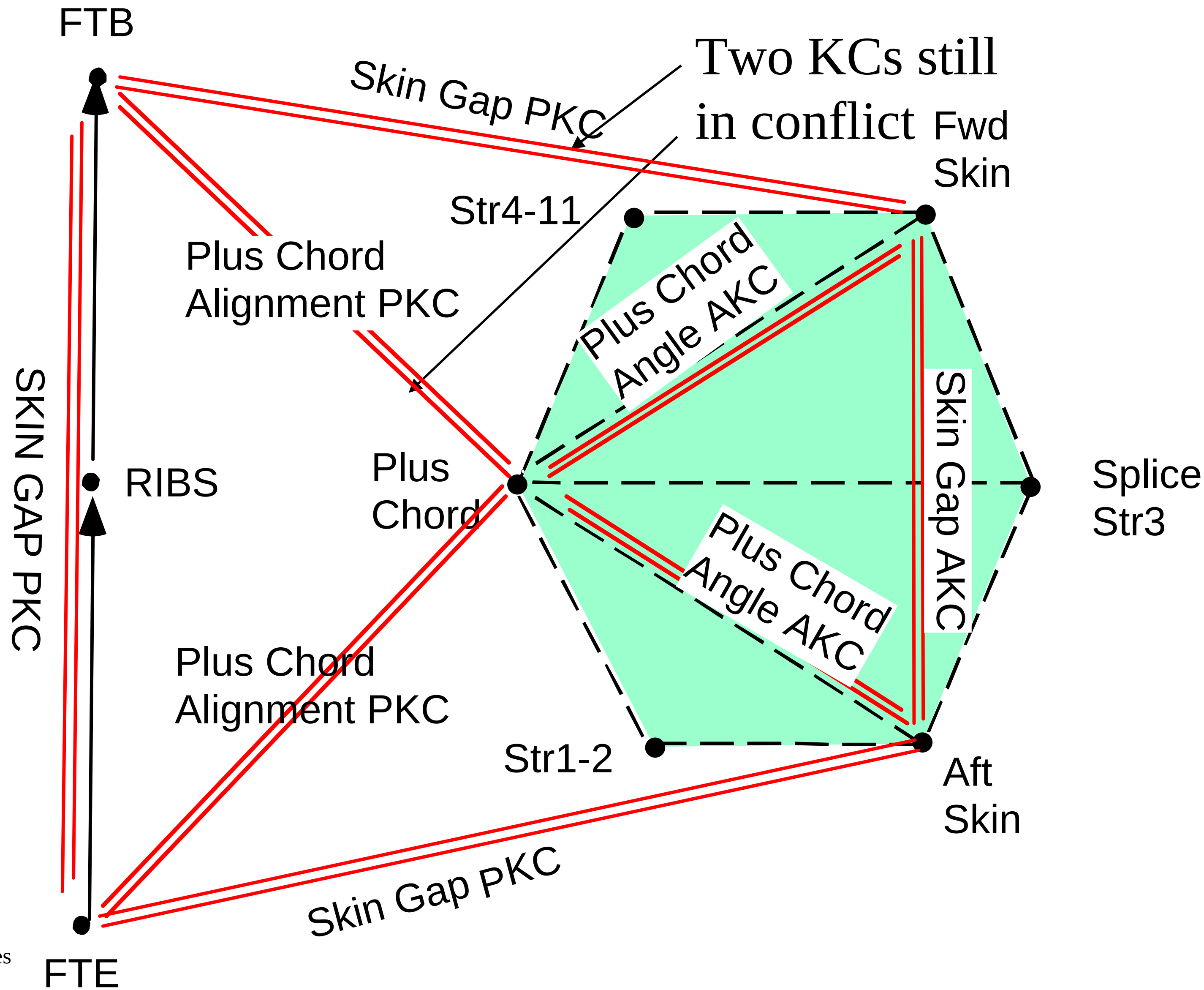
Step 3: Add FTE

FTB-Rib-FTE assy

DFC for Rib-Spar as a Type-1

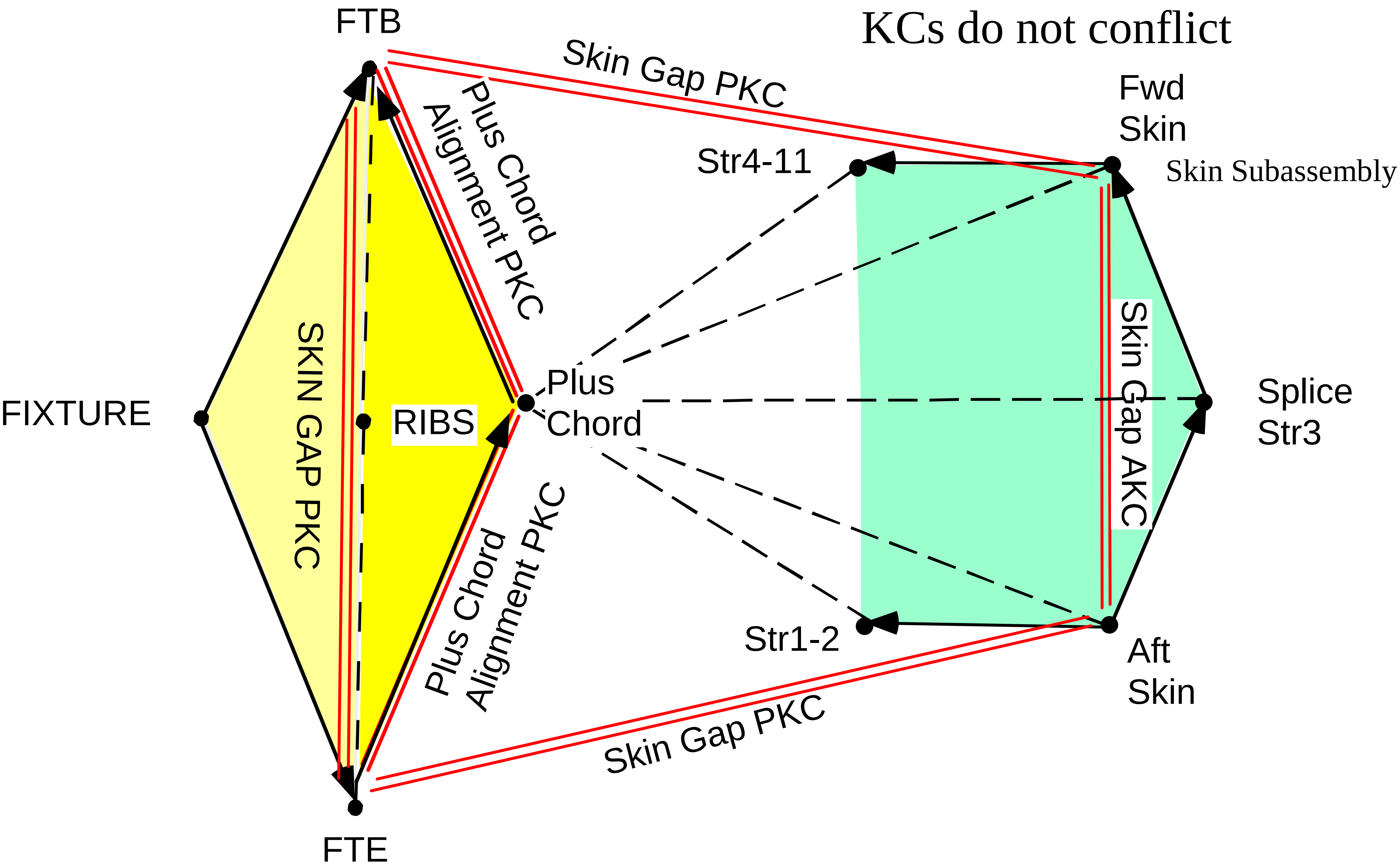


DFC for Wing Assembly as a Type 1

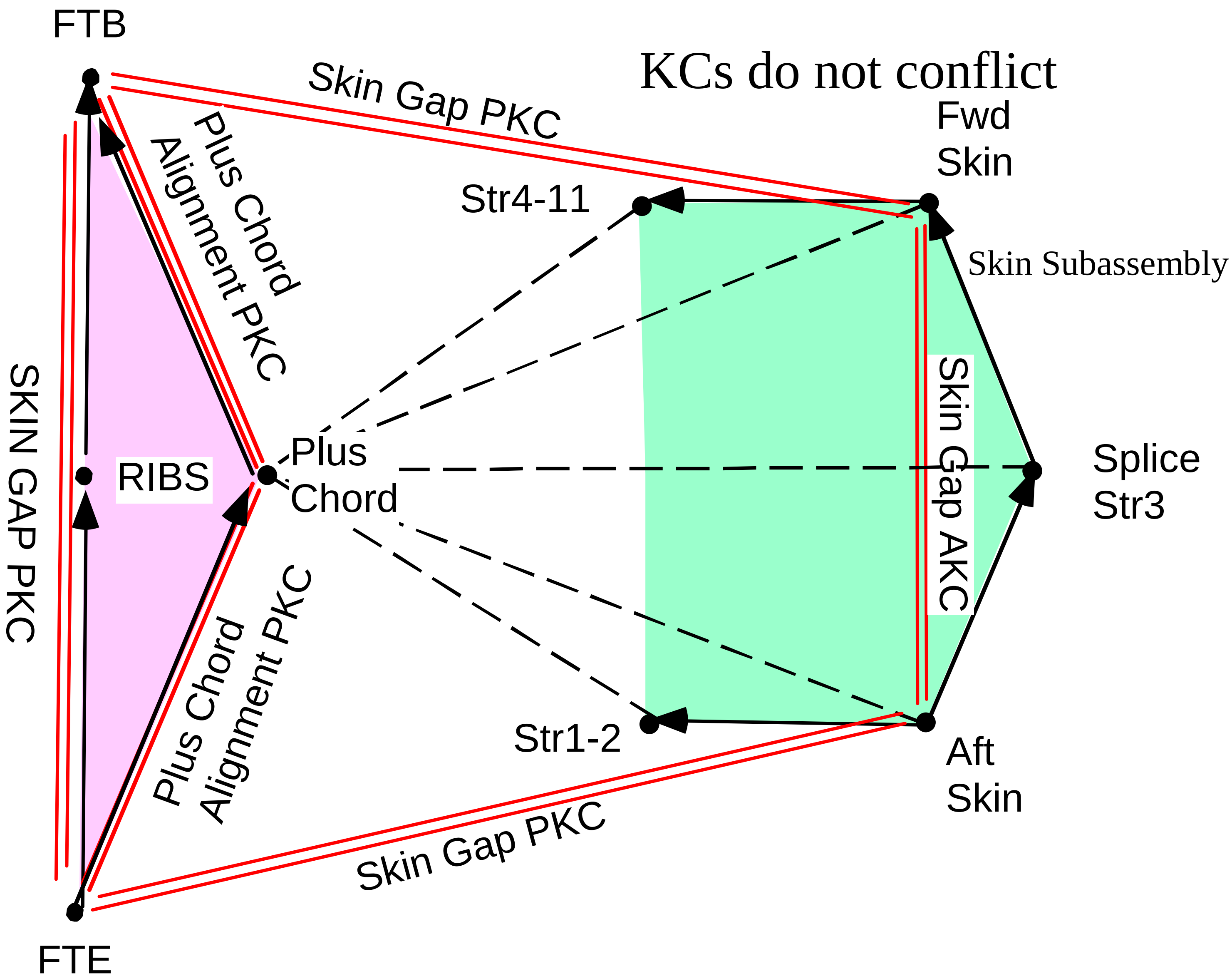


figs for designing assemblies

"Impossible" as a Type 2



“Impossible” as a Type 1



Cost Analysis -1

- The basis for analysis was the KC-driven Precision Assembly (PA) process for the 767 horizontal upper skin assy.
- PA time and cost were estimated for the 767 skin
- The 767 cost/time analysis was scaled for the remaining 747 & 767 assemblies Vought makes for Boeing.
- PA assumed to be accomplished in three distinct cells: Tack, CNC Auto-Rivet, Final Assembly
- These cells all require new investment

Cost Analysis - 2

- Baseline times for each step were taken from Vought's estimates for its process.
- Required cell time for MIT's processes was estimated based on Vought's times and a distribution of realization factors applied to obtain an assembly time for each cell.
- A computer simulation was conducted to determine the necessary capital equipment.

Simulation Scenarios

- Three PA processes were developed and analyzed.
  - The 3 processes are “Vought,” “MIT 1,” and “MIT 2”
  - “Vought” is Vought’s proposed PA process
  - “MIT 1” uses holes and slots. It was derived from “Vought” by applying the KC flowdown method. “MIT 2” uses NC tack cell
- Three scenarios were studied:
  - All Boeing assemblies, all programs
  - Four representative assemblies
  - Introduction of a new assembly
  - New assembly would require new fixed tool but not new PA equipment
- One and Two shift operations

Results - 1

- PA estimated to reduce process time by approximately 50%. At current demand this results in approximately XX hours saved annually.* Value of flexibility, “image,” and freed-up floor space not included.
- Annual savings = $X Million (assumes all assemblies converted to PA at a rate of $XX/hour.)
  - VOUGHT TO BE = 54% OF AS IS TIME
  - MIT 1 = 43% OF AS IS
  - MIT 2 = 42% OF AS IS
  - *ACTUAL NUMBERS ARE PROPRIETARY

Results - 2

- Estimated equipment investment to implement PA (example for MIT 1)

	All Parts	4 Parts
One Shift	$21.4M	$14.1
Two Shifts	$14.1M	$7.3

(assumes cost per cell is Tack $2M, A-R $4.8M, Final Assembly $0.5M)

Results - 3

- Current economics did not justify the new process
- The new process becomes economical if Vought gains new business for which it can use the new cells, thus saving the cost of new hard fixtures
- Training and cultural issues remain to be evaluated
  - Adjusting by hand becomes adjusting via computer
  - Ad hoc process becomes a preplanned and designed one requiring more manufacturing knowledge during design
  - More communication between fab and assembly shops needed