RDS^{win}: Seamlessly-Integrated Aircraft Conceptual Design for Students & Professionals

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RDS^{win} is an aircraft conceptual design computer program that includes design layout, design analysis, and system optimization – the three critical legs of any vehicle design effort. RDS^{win} is a single compiled executable that includes an aircraft-oriented Design Layout Module (CAD) and a full set of aircraft analysis and optimization routines, accessed from the same pulldown menu and using the same input/output routines. In this paper the methods and features of RDS^{win} are presented, with emphasis on those that help justify the title cliché, "Seamlessly-Integrated."

Nomenclature

A	= Aspect Ratio (span^2/reference area)
API	= Application Programming Interface
CDS	= Rockwell Configuration Development System (CAD program)
kB	= Kilobyte (10^3 bytes of information)
fs	= Ps per unit fuel flow
L/D	= Lift-to-Drag Ratio
M	= Mach Number
mB	= Megabyte (10^6 bytes of information)
MDO	= Multidisciplinary Design Optimization
Ps	= Specific Excess Power
RDS^{win}	= Aircraft design software package *("Raymer's Design System")*
ROAST	= RDS Optimal AeroSpace Trajectories
T/W	= Thrust-to-weight ratio
W_e	= Aircraft Empty Weight
W_o	= Aircraft Takeoff Gross Weight
W/S	= Wing loading (weight/area)

I. Introduction

The RDS^{win} aircraft conceptual design software has been developed to take an aircraft design from first conceptual layout through functional analysis, leading to performance, range, weight, and cost analysis, and including design optimization by classic carpet plots and modern MDO. Neither a spreadsheet nor a math package implementation, RDS^{win} totals over 88,000 lines of original source code plus 120mB of resource, text, library, and image files.

RDS^{win} has its own aircraft-oriented CAD module and includes powerful capabilities for the analysis of aerodynamics, weights, propulsion, and cost. It has full-capabilities for aircraft sizing, mission analysis, and performance analysis including takeoff, landing, rate of climb, Ps, fs, turn rate, and acceleration. RDS^{win} provides graphical output for drag polars, L/D ratio, thrust curves, flight envelope, range parameter, and more.

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RDS^{win} comes in two versions. The Student version was created to accompany Dr. Raymer's textbook in the classroom where it allows the neophyte to rapidly create a credible design and do the required analysis. This frees up time to learn the overall design process including the all-important design iteration loop. The Professional version of RDS^{win} adds greater accuracy and a suite of expert features to help the designer in an industry or research environment, notably the built-in optimizer, a trajectory module[1] (ROAST), automated trade studies, and IGES geometry export.

Various details of the RDS^{win} program have been presented previously[2,3,4]. The sections below will focus upon the specific methods that tie together design, analysis, optimization, and redesign in a way that can truly be called "seamlessly-integrated."

II. One Single Executable

The first feature of RDS^{win} that facilitates its seamless integration is simple – it is all just one big program. Many such computer programs, including the Rockwell-Boeing IDAS/CDM that this author helped developed years ago[5], are Frankenstein assemblies of separate design, analysis, and optimization programs which were written by different people at different times for different purposes. These disparate codes are either separate executables which are brought to the foreground as needed, or are pasted together from their separate parts and then compiled.

With RDS^{win}, all of its design layout, analysis, and optimization occurs within a single program executable. It was all written together, using the same IO subroutines, global memory allocations, resource files, and graphics utilities. It all uses the same user interface including pulldown menu, on-screen buttons, and expert's hot keys. While the word "module" is used in the documentation for differentiating the various portions of the program, there actually are no separate modules. It's all one code.

Thus, there is no "throwing it over the wall" from CAD to analysis to optimization because there is no "wall." It's all the same program, defined and developed as an integrated whole. The CAD geometry is directly available to the analysis and optimization routines since it is read into global variables in the program.

III. User Interface

The main user interface is a single pulldown menu with 551 menu and submenu commands. figure 1 shows its options for component shaping and performance analysis, illustrating that in RDS^{win} the CAD and analysis are all part of the same user interface. There are also Windows* pop-up menus and selection boxes for inputs, program options, and filename selection.

It was decided from the start to provide single keystroke "hotkeys" to speed up program operation by experts. Regular users get tired of going through several levels in a pulldown menu to do something as simple as graphing the data already seen on the screen. Each hotkey command can also be done through the pulldown menu, but pressing a single key is more convenient. Below is a small sample of the available hotkeys:

- P	Print
- G	Graph current input grid
- H	Help (including available hotkeys)
- A	Do Analysis
- Z	Zoom
- M	Measure
- L	Locate
- B	Save Bitmap of screen
- I	Isometric drawing
- R	Rendered drawing
- #	Toggle between Imperial and Metric Units

Implementing these hotkeys proved troublesome. When a pulldown menu is active, mouse and key inputs are normally routed to the pulldown menu Windows API routine. To check for the press of a hotkey required implementing a timer interrupt function to check for a key press throughout the time that the pulldown menu is waiting for its expected inputs.

For the input of large amounts of data such as needed for aerodynamic analysis, an all-new input grid routine was developed for RDS^win^. This is directly integrated into the code and is tailor-made for aircraft-oriented data input. It allows rapid input of required data, automatically sets analysis defaults, and guides the user as to proper inputs. A portion of a typical input grid is shown as figure 2.

These input grids are either two-variable arrays, such as parasitic drag versus speed and altitude, or are paired columns of data such as stores drag versus Mach #, or are paired columns of data and labels. The grids are airplane specific and include pop-up help text for each input column, providing brief explanations and required units for the data to be entered.

Another aspect of the user interface that facilitates integration both within RDS^win^ and between it and other programs is the variety of output formats for analysis results and input file printout. RDS^win^ lets the user select any of six different displays, including via other programs such as Excel and MS-Word.

The default option is to show the text on the RDS^win^ Console (background screen, looks like DOS but it isn't). The screen is cleared completely, even the pulldown menu, and the text appears. This provides the maximum amount of room for text. You can also choose to show the text in a small pop-up box.

Other options send the text to whatever Windows program your computer system identifies as the default for opening such files. If you select "Use My Word Processor," RDS^win^ will create a file with filename extension .DOC and ask Windows to open it. Windows will start your word processor (usually MS-Word) and open the file.

Similarly, if you select "Use My Spreadsheet," RDS^win^ creates an XLS file which most computers will open in Microsoft Excel.

If you select "Use My Web Browser" then RDS^win^ will write a complete web page in HTML format and open it with your browser (Internet Explorer, Firefox, etc…). This is especially useful because resulting web page can be posted on the Internet or emailed to others. They will be able to see exactly the same results that you see, even if they don't have RDS^win^.

Note that when RDS^win^ uses the Web browser for display, it is entirely local to your computer. You don't need to have an Internet connection to use your Web browser for display, nor does RDS^win^ "talk" to the internet on its own.

This ability to write and display a web page of analysis results or input data is actually a remnant of the biggest mistake made during the years of coding RDS^win^. At first, an attempt was made to use HTML code and the user's web browser for all data input. A Java utility was written that could read values from HTML Forms from wherever the data was stored locally on the user's hard disk. Software was then written to decode the data and load it into the RDS^win^ variables and program control parameters.

This worked very nicely and had the advantage of looking like a webpage input form, which everybody is familiar with (see **Error! Reference source not found.**). However, a major upgrade to the Windows operating system at that time changed the disk location of the Forms data. Suddenly, the HTML-based RDS^win^ input screens no longer worked! While it was possible to fix it for that Windows release, what about the next one? And the next?

This seemed too risky, so those ~5,000 lines of code were thrown away. All that was used was the nice routines that write HTML and "wake up" the user's web browser. Instead, an all-new RDS^win^ input grid routine was created as described above. It's actually much better than the HTML forms-based input scheme.

IV. Airplane-Oriented Cad

The RDS^win^ Design Layout Module (DLM) is an all-original set of CAD routines developed just for new air vehicle conceptual design. It is not a separate or linked program as for some other aircraft design packages, nor was it adapted from a generic CAD program developed for other uses. Despite being called a "Module," the DLM is an integral part of RDS^win^, being a number of design commands which are coded and compiled with the rest of RDS^win^ and called from the same pulldown menu.

The RDS^win^ CAD geometry is specifically defined to make it easy to manipulate the aircraft configuration, both through user commands and through automated routines that reconfigure the design based on sizing and optimization results. Furthermore, the program "knows" what an airplane is, and has automated routines for quickly creating most of the components used in aircraft design.

A fundamental feature that facilitates initial aircraft design and helps with the integration of design, analysis, and optimization is its use of "components" as the basic unit of data storage. These are based on standard aircraft terminology - wing, tail, fuselage, tire, etc… Normally each component represents a single closed object.

Each component in RDS^win^ has its own local axis system. Its location and orientation within the aircraft global axis system is readily changed. Each component has a header file with information used in RDS^win^ to set display options, define component symmetries, record creation date, and other information such as the original reference geometry for wings and tails.

Each component file includes the actual component geometry which is stored as YZ cross sections stacked in the X direction, using either point or Bezier representation (see below). Non-planar cross sections are also permitted for shapes such as a canted inlet front face, like in the F/A-18E/F.

RDS^{win} components are defined in one of three mathematical formats. The simplest form, often used for internal components, uses actual surface points stored as cross-section lines. For wings and tails these points are the actual airfoil coordinates, stretched and scaled using RDS^{win} routines to create the desired aerodynamic surface geometry.

For a mathematical definition of cross-sections, a variation of the parametric 4th degree polynomial Bezier Curve is used. This "SuperConic" curve[2] looks like a classical conic to the designers, despite its greater power. Both curves have two endpoints and an on-the-curve shoulder point. Both have lines from the endpoints that control the tangent angles. The only difference is that in the SuperConic, each endpoint has its own point controlling tangent direction and they can be placed independently, even on opposite sides of the desired curve. Also, reflexed curves are permitted unlike in a regular Conic.

Routines in RDS^{win} make it easy to drag the points around on the screen in cross-section and side/top views.

Point and SuperConic cross-sections can be used to define a component in RDS^{win}-Student. A third method, the SuperConic Surface component, is available in RDS^{win}-Professional. This permits creating true surfaced components and designing smooth shapes in the longitudinal direction. These three options are shown in figure 4.

RDS^{win} design data are saved as a simple text file which makes it easy for outside programs to manipulate the data to redesign the concept. This file format is also very efficient, needed less than 100kB for a typical design in RDS^{win} versus about 4mB when the same design is exported as an IGES file.

A typical design example is shown in figure 5, with external and internal components each defined as described above. The header file and first two cross sections of this design's fuselage component are as follows, with explanatory comments in brackets:

```
RDS-Pro Version win8.2
DanBus2-1.dsn
10-24-2015 {08-01-2014} 09:28:30
D. Raymer
Short-haul Airline & Cargo
DanBus2
0,0,0,0,0,0,0,0,0                    [Wo, Wf, We,..]
Short-haul STOL airliner
{C:Fuselage}
0,0,0,0,0,0                          [X,Y,Z,roll,pitch,yaw]
-1,2,0,0,"11111"                     [sym,geom,..]
DanBus Fus                           [user input ID text]
031-000:Fuselage                     [SAWE code]
08-03-2014
0,0,0,0,0,3                          [Wt & cg info]
 49.17131 , 3.5 , 7.472312 , 0 , 0
 0 , 0 , 0 , 0 , 0                   [comp data]
 0 , 0 , 0 , 0 , 0                   [wing param]
 0 , 0 , 0 , 0 , 0
 0 , 0 , 0 , 0 , 0
19 pass 2-LD3                        [user input text]
13,1,41                              [#sect,1=planar,drawpt]
-1.563927,9                          [X, # pts]
.0,-1.872008                         [Y,Z]
.1856533,-1.872008
.2083588,-1.8921
.245128,-1.904507
.245128,-2.005953
.245128,-2.127892
.2206152,-2.126504
.223155,-2.139899
.0,-2.139899
-.6629171,9                          [X, # pts]
.0,9.705202E-2                       [Y,Z]
1.529327,9.705202E-2
2.180823,-.1783937
2.845002,-.4527528
```

```
2.845002,-1.055454
2.845002,-2.304434
2.164789,-2.862014
1.480262,-3.421194
.0,-3.421194              (plus 11 more sections)
```

V. Component Type Codes

One of the important "seamless integration" features of the RDS^{win} Design Layout Module is its component type code scheme. Each component stores a six-digit type code based on the Group Weight Statement categories in SAWE specification RP8A (previously Mil-Std-1374). This allows RDS^{win} to "know" which sort of analysis is appropriate for which components, and which sort of scaling and reshaping logic should be followed when the user or a sizing/optimization result needs to rescale the whole airplane.

Type codes are defined in the following major categories:

- Wing
- Rotor Tail
- Fuselage
- Landing Gear
- Nacelle & Eng Sect
- Propulsion
- Equipment
- Useful Load
- Non-Physical Comps

For each major category there are specific component type codes, such as these Wing examples:

- 002-000:Ref Wing
- 002-003:LEX
- 002-004:Winglet
- 002-005:Wing Strut
- 002-999:Wing-Other
- 008-000:Aileron
- 008-001:Elevon
- 009-000:Spoiler
- 010-000:Flaps (TE)
- 011-000:Flaps (LE)
- 012-000:Slats
- 031-000:Fuselage
- 031-001:Canopy
- 085-000:Instruments
- 086-000:Hydraulics
- 087-000:Pneumatics
- 088-000:Electrical
- 090-000:Avionics

These are automatically set when using one of the many "canned" component creation routines, or can be selected in a pick menu. For the full set please contact the author.

For example, when a wing is created the user is prompted to select the type of wing. If *002:000:Ref Wing* is selected, that code is stored with the wing component. When the design is completed and the geometric information is collected for aerodynamic analysis, RDS^{win} will recognize from this code that the area of this wing is to be used as the reference area for the calculated aerodynamic coefficients. Furthermore, the *002:000* code tells the Weights Module to use a certain wing weight equation, and the code knows which geometric information to extract from the component to populate the weight analysis input fields.

VI. Tab File: Geometry To Analysis

Another unique feature to facilitate integration between design, analysis, and optimization is the RDS^{win} TAB File. This is a massive tab-delimited file of key design geometric information, and contains wing and tail data blocks, component information, and component cross section perimeters and areas.

The information for each component includes length, width, height, a-max, l/d-equiv., total surface area, surface area+ends, total volume, X, Y, Z (location), roll, pitch, yaw, centroids (local and global axis system), and moments of inertia. The component type code is also listed for each component, allowing the analysis modules to know what equations to apply. A small portion of a typical TAB file can be seen as figure 6

The TAB File is instantly created by the Analyze command in the Design Layout Module. Then it can be used to read your design's geometric information into the Aerodynamics, Weights, and Propulsion modules. When the TAB file creation is finished, DLM will offer to open it in your spreadsheet for review, and it can be passed to other members of a project team to answer most of the usual geometric questions about a new design.

VII. Aircraft Data File: User In Charge

One unusual feature of the overall structure of RDS^{win} was deliberately defined to improve the integration between design, analysis, and optimization. It also makes it easy for the user to do unusual things beyond the program's normal methodologies. This refers to the way that a design's functional analysis results (aero, weights, and propulsion) get to the performance, range, and sizing calculation routines.

Other papers[6] have focused upon the functional analysis methods used within RDS^{win}. These are mostly based on calculations described in the author's textbook *Aircraft Design: A Conceptual Approach*[7].

To provide both integration and flexibility, these functional analysis calculations are NOT done during the mission sizing and performance calculations. They are done before-hand and stored in a collection of data arrays called the *Aircraft Data File*.

The Aircraft Data File is like a filing cabinet. You fill it with data from the Aerodynamics, Weights, and Propulsion modules, then those numbers are pulled out and used when you run the mission sizing and performance calculations.

RDS^{win} works this way for several reasons. When you are calculating something like rate of climb, RDSwin doesn't have to recalculate the drag coefficients. It just pulls them out of the "Aero drawer" in the "filing cabinet". This is much faster, especially for the big optimizations in RDS^{win}-Pro.

This program structure also lets you review and approve the analysis results before they are committed to range and performance calculations. RDS^{win} facilitates this by stepping through graphs of all the stored data, with a single pulldown command. And, it's easy to correct data that you don't like.

With this method you can quickly do trade studies. Various tools let you scale or change these data items and then redo the mission sizing and performance calculations. For example, you might multiply the whole parasitic drag data array by 1.2 to determine the effect on range and rate of climb of a 20% increase in CD0. In a study for NASA, this was used to create parametric inputs into commercial regression software, resulting in a Response Surface model for further investigations. The Aircraft Data File approach made this easy.

Finally, this filing cabinet approach lets you "mix and match" your data. You don't have to use the RDS^{win} calculations exclusively. For example, you could type in wind tunnel data for aerodynamics, copy the propulsion data from a similar aircraft, use RDSwin to estimate the weights, and then use this mash-up to calculate range and performance.

The Aircraft Data File includes weights data, CD0, K, CL-max, CL-alpha, installed engine thrust, specific fuel consumption, and certain other parameters. This is all contained in seven separate input grids, mostly in array format as a function of one or two variables such as velocity and altitude. RDS^{win}-Pro also permits seven additional arrays containing part-power specific fuel consumption data, and two more tables defining minimum thrust.

VIII. Built-In Optimizer

The optimization capabilities of RDS^{win} can be called "seamlessly integrated" because they are built right in to the code, part of the single executable and accessed through the same pulldown menu. Optimization inputs are defined in an input grid just like all the other analytical parts of the program, and the various optimization methods use the same analytical input files that the user has already defined. It literally takes seconds to set up and run a classic carpet plot, a deterministic stepping search, or a stochastic evolutionary or Genetic Algorithm optimization.

Through the input grid, the user can change various options and defaults including the measure of merit, the parametric range of the design variables and the real-world constraints that are to be applied (length, span, volumetric density, etc…).

Note that the RDS^{win} optimizer is very specific to those design variables with the greatest impact on an overall aircraft conceptual design, namely T/W and W/S plus the wing trapezoidal planform parameters, i.e., aspect ratio, taper ratio, sweep, and wing airfoil thickness ratio. Two more variables are included, the fuselage fineness ratio and the wing design lift coefficient (surrogate for camber optimization).

Measures of Merit for optimization include takeoff gross weight, empty weight, fuel weight, purchase price, life cycle cost, or internal rate of return. Optimization is done in the face of performance requirements including takeoff, landing, turn, Ps, climb, and acceleration, with required values defined in the Performance Analysis input grid.

IX. Automatic Redesign From Sizing And Optimization Results

Another uniquely-integrated capability of the RDS^{win} CAD module is its ability to automatically modify a design based on the results of sizing analysis and design optimization. This allows the designer to return to the design layout and instantly see the affect of the changes, and then fix, modify, or reject them as desired.

This automatic redesign is “smart,” using the component type codes described above to change the various components automatically as appropriate to their type. A wheel doesn’t scale the same way as a wing. The methods were detailed at a previous AIAA Aerospace Sciences Meeting[8] and are summarized below.

The most important result of either sizing or optimization is a new value for the takeoff gross weight. This changes everything about the design, from the sizes of the wings and tails, to the required engine thrust and inlet duct diameter, to the wheel diameter and even the height of the aircraft above the ground.

With a normal CAD system the designer will have to spend a lot of time laboriously fixing all these things. RDS^{win} does it automatically, using the following rules:

- Fuselage scaled by cube root of weight ratio, unless length constrained by user input
- Wing area scaled proportional to weight ratio
- Tails scaled by 3/2 power then adjusted based on change in fuselage length, to hold constant the tail volume coefficient
- Engine scaled assuming T/W constant, using empirical exponents for diameter and length vs. thrust ratio (unless disabled)
- Nacelle and inlet duct scaled in diameter by square root of thrust ratio
- Wheels and tires scaled based on statistical tire diameter and width equations
- Gear shock-strut diameters scaled by square root of weight ratio
- Ground plane and tail-down angle components scaled proportional to fuselage scaling

When a full optimization is done, RDS^{win} will also automatically change the wing planform and fuselage geometry to match the new optimized values of wing area, aspect ratio, taper ratio, sweep, airfoil thickness, and fuselage fineness ratio.

The wing planform revision is done in a parametric manner using mathematics developed by the author that stretches and slides the actual wing geometry to reflect the difference between the old and new trapezoidal reference wing. The same is applied to any derived components, such as a wing box, spar, fuel tank, flap, or aileron. Thus, RDS^{win} gets the benefits of parametric modeling without the downside limitations on flexibility.

Note that the optimized value for wing design lift coefficient is not directly applied to the geometry. Instead it becomes a target for the aerodynamic department’s subsequent airfoil shape, twist, and camber optimization. This is controversial. Some other code developers include such 3-D wing optimization directly within the optimization. In this author’s opinion it is better to optimize the aerodynamic design *target*, not attempt to do in a single computer code what a team of aerodynamic experts will do over a period of months, using high-end CFD tools and wind tunnel testing.

If volumetric density was used as a constraint, RDS^{win} will also enlarge the fuselage as needed to maintain sufficient volume should the wing grow smaller or thinner.

This automatic redesign tool will significantly reduce the time to complete a design iteration going from the initial “Dash-1” design to the optimized “Dash-2”. Of course, such automatic scaling cannot be expected to produce perfect revised geometry but it can do most of the “grunt work” associated with revising a design layout to match the improved design parameters.

A re-shaped commercial airliner is shown in figure 8, where area, aspect ratio, taper ratio, and sweep of a wing have been instantly changed based on optimization results. The non-trapezoidal features of the original wing design are preserved, scaled proportionally to the changes in the planform parameters. The fuselage fineness ratio has also been increased as per the optimization, but a minimum diameter constraint was employed. Tail sizes have been reduced since the longer fuselage has increased their moment arms.

[Note to Students: Sorry, but RDS^{win}-Student does not have the optimizers or the automatic redesign tools. You are supposed to be learning how to do such things, not learning how to push a magic button! Instead, RDS^{win}-Student makes it easy for students to quickly do all the calculations to graphically construct their own trade studies and carpet plot graphs. Some universities also get a single copy of RDS^{win}-Pro that the students can use after they've built their input files in RDS^{win}-Student.]

X. Design Example Showing Seamless Integration

As a sample of the seamless integration between design, analysis, optimization, and redesign, a recent aircraft design study is presented. This looked at an optionally-manned multirole UAV designed for extensive modularity[†]. It has a core vehicle with wings, tails, propulsion, fuselage, and vehicle subsystems. The left side of the cockpit region is removable and can be replaced with modules providing an extended weapons bay, cannon, buddy fuel tanks, sensors, and the like. A small portion of the forebody on the right side of the cockpit is not removable, and carries the nose landing gear and the one-side-only pitch control canard.

After initial sizing, the overall configuration was developed in RDS^{win} as shown in figure 9. It was designed to a takeoff gross weight of 12,000 lbs and is 36 feet in length. Note that the CAD file contains multiple components for the same regions, most notably the cockpit area where a stretched weapons bay is superimposed. These are modular features, and the airplane would never fly with them all installed.

The geometric information was extracted from the design layout and a TAB file was created, as shown in figure 10. From the TAB file the geometric information needed for analysis was read into the RDS^{win} input grids for aerodynamics and weights, with calculation results as shown in figure 11 and figure 12. These results, including aerodynamics at different speeds and altitudes, were loaded into the Aircraft Data File. For this design, an already-available installed engine data set was simply copied into the Aircraft Data File so the RDS^{win} propulsion module wasn't used.

Using this data, the aircraft range was calculated over a high-low-high mission, and found to be about 600 nmi (radius). The cruise altitude and velocity optimization capabilities of RDS^{win}-Pro were used during this calculation.

Next, a Carpet Plot (figure 13) was created to review the performance inputs and requirements, and then a Genetic Algorithm optimization was performed (figure 14).

From the optimization results, the geometry was automatically revised as shown in figure 15. As can be seen, the optimization reduced wing sweep but increased aspect ratio, and substantially increased fuselage fineness ratio. These caused a substantial drop in the aircraft TOGW which made the engines and nacelles smaller. With the greater fuselage fineness ratio, the aft end of the vehicle is no longer lined up! This will have to be fixed. Luckily, RDS^{win} still allows a human designer to make the final design decisions!

XI. Summary & Conclusions

The architecture and methods of RDS^{win} have been defined to create a seamless integration between design layout, design analysis, and system optimization, and thus to allow the designer to focus upon the real job at hand. The following aspects of the program, methods for which have been described above, are most important:

- Single program EXE with single pulldown menu
- Built-in CAD with airplane-specific design/redesign routines
- Aircraft defined as collection of components with type ID
- Automatic geometric data extraction for analysis (TAB file)
- Changes to design can be auto-updated to analysis input files
- Built-in classical aircraft analysis methods
- Aircraft Data File collects analysis results and allows mix-and-match of data sources, plus scaling and adjusting of data ("fudging")

[†] Permission has been granted by the customer to show this study and reuse its RDS^{win} design files

- Built-in optimizer that can modify design to match its results

RDS^{win} and its DOS predecessor have been used to design and/or analyze a wide variety of vehicles for organizations including DARPA, RAND, USAF-AFRL, NASA, Boeing, and Composite Engineering. Vehicle types include airliners, supersonic stealth fighters, UAVs, airships, personal aircraft, reusable launch vehicles, and more. Comparisons with known aircraft data has been good, and performance predictions have been validated in flight.

A key reason for its success to date has been the flexibility and speed of use brought about by the seamless integration described above.

Figures:

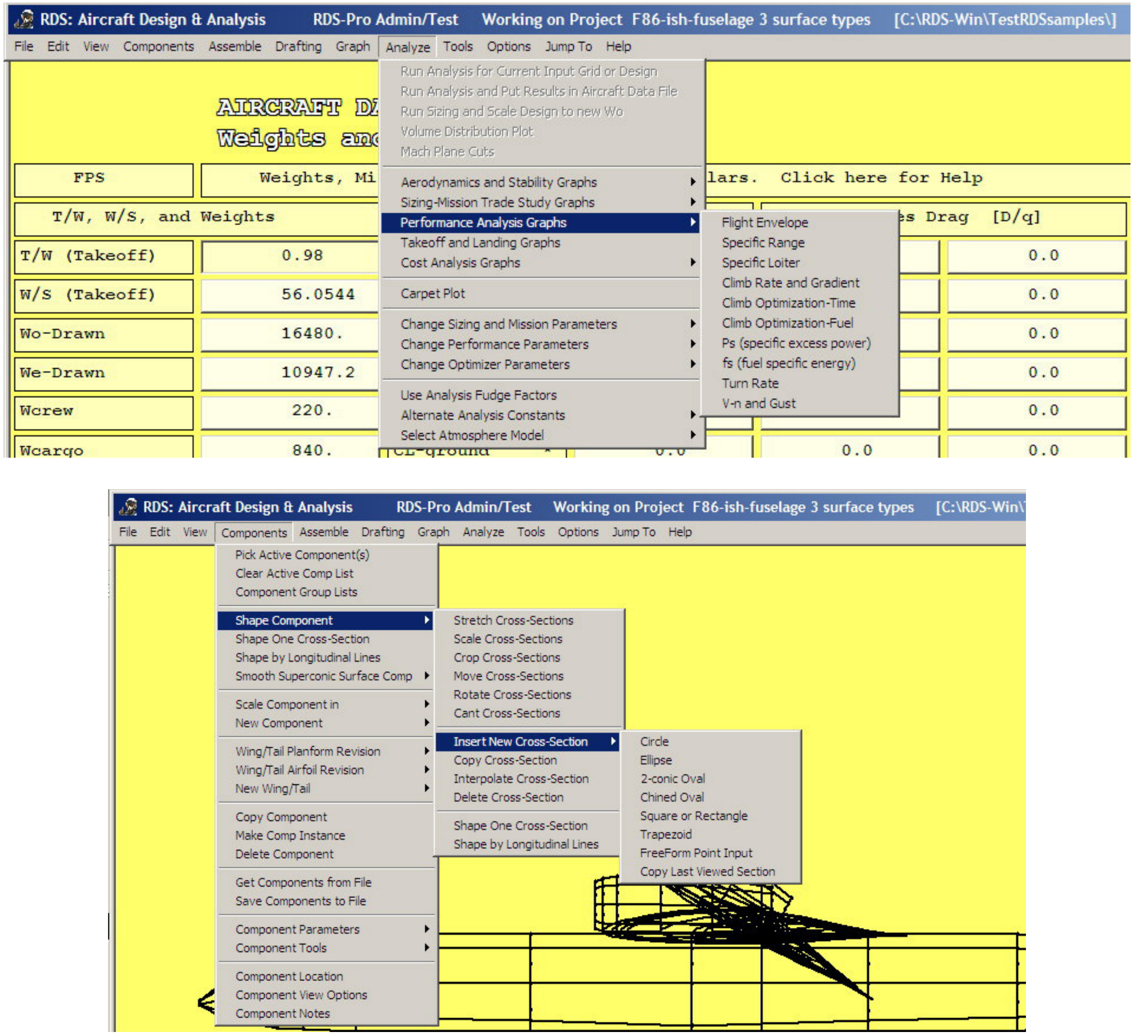
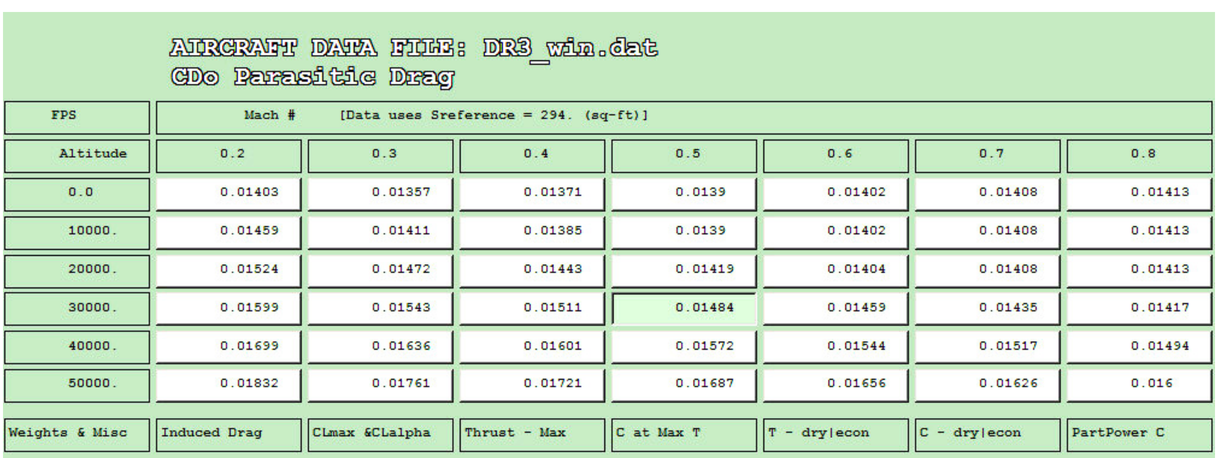


figure 1. Single Pulldown Menu for CAD, Analysis, and Optimization



AIRCRAFT DATA FILE: DR3_win.dat
CDo Parasitic Drag

FPS	Mach # [Data uses Sreference = 294. (sq-ft)]						
Altitude	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.0	0.01403	0.01357	0.01371	0.0139	0.01402	0.01408	0.01413
10000.	0.01459	0.01411	0.01385	0.0139	0.01402	0.01408	0.01413
20000.	0.01524	0.01472	0.01443	0.01419	0.01404	0.01408	0.01413
30000.	0.01599	0.01543	0.01511	0.01484	0.01459	0.01435	0.01417
40000.	0.01699	0.01636	0.01601	0.01572	0.01544	0.01517	0.01494
50000.	0.01832	0.01761	0.01721	0.01687	0.01656	0.01626	0.016
Weights & Misc	Induced Drag	CLmax &CLalpha	Thrust - Max	C at Max T	T - dry|econ	C - dry|econ	PartPower C

figure 2. Typical RDS^{win} Input Grid (Parasitic Drag)

FPS	Mach #					
Altitude	**0**	**.5**	**.9**	**1.2**	**1.6**	**2**
0	32000.	34251.	37516.	38649.	39973.	30252.
20000	16000.	16857.	24241.	26811.	27650.	23648.
36000	8533.33	8919.67	12687.	15055.	19700.	17154.
50000	4266.67	4568.65	6621.84	8199.27	9690.32	8945.20

FPS	W/S (Takeoff)	T/W (Takeoff)	#Engines	Nmax	q-max	FPS
	56.0544	.98	1	7.3333	2200	
Wo-Drawn	We-Drawn	Wcrew	Wcargo	Wpassenger	Wmisc UL	Woil
16480	10947	220	840	0	0	50
Available Fuel W_f = 4422.8 (lbs-m)				W_{empty} Sizing Coefficient (C)		-.19343

figure 3. Use of Webpage Forms for Data Input (discontinued)

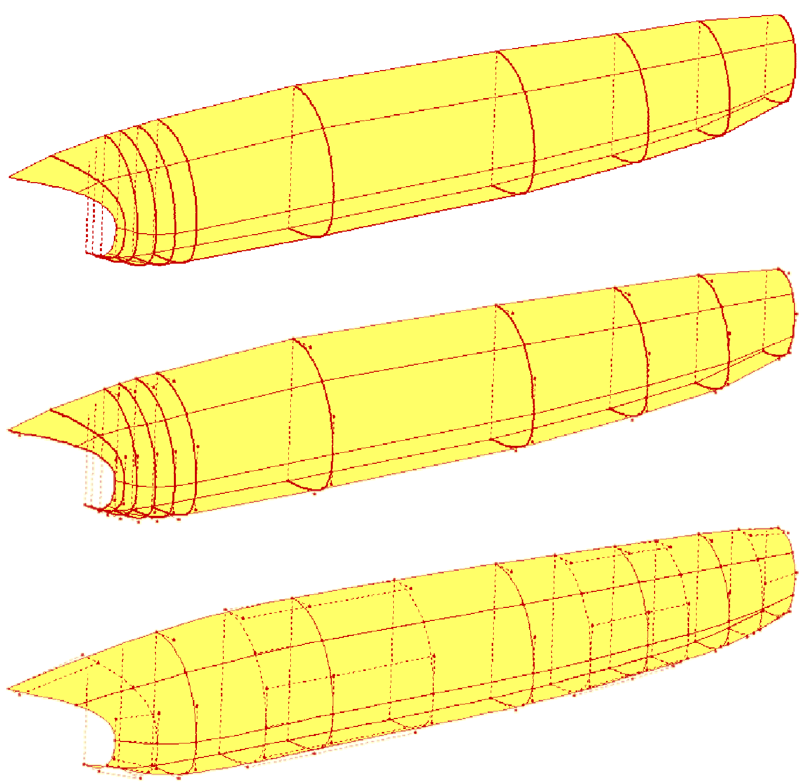


figure 4. Three Component Geometry Formats (Point, SC Section, SC Surface)

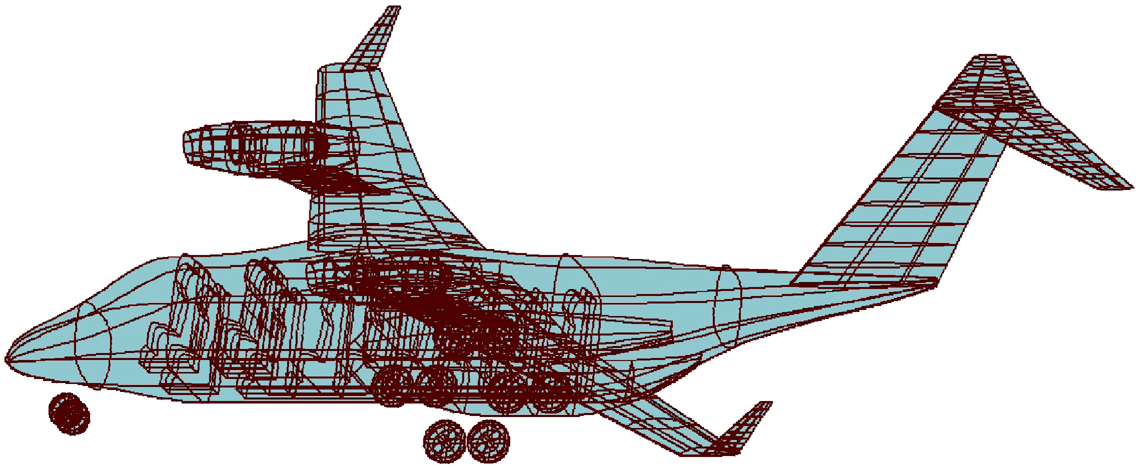


figure 5. Components Defining an Airplane

Component	SAWE8 Code	Length	Width	Height	A-max	l/d-equiv.	Total Surface Area	SurfArea +Ends	Total Volume	# comp	X	Y	Z	Roll	Pitch	Yaw	Xcentroid	Xc-global
Wing	[002-000]	12.226	10.188	1.047	6.055	4.403	278.869	285.703	66.041	1	20.8	0.0	-1.6	-2.0	0.0	0.0	5.425	21.979
CANOPY	[031-001]	23.532	1.832	3.225	4.626	9.696	102.013	102.447	65.282	2	8.1	0.0	2.2	0.0	0.0	0.0	8.001	16.068
Hor Tails	[020-001]	6.854	5.957	0.426	1.21	5.522	43.718	45.192	4.661	2	32.7	2.7	-0.4	2.0	0.0	0.0	1.759	32.859
Fuselage	[031-000]	34.754	4.2	4.721	17.44	7.375	412.019	413.331	406.078	1	0.0	0.0	0.0	0.0	0.0	0.0	16.685	16.685
Nacelle	[055-000]	19.404	3.285	4.054	6.76	6.614	172.836	181.218	115.684	2	15.5	0.0	0.2	0.0	0.0	0.0	9.621	25.082
Main Wheel	[040-001]	0.434	1.633	1.633	2.09	0.266	3.168	5.216	0.816	2	23.0	3.2	-3.9	0.0	0.0	0.0	0	23.031
Gear Leg Sh	[041-001]	2.971	0.25	0.927	0.13	7.312	2.498	2.519	0.159	2	23.3	2.1	-1.4	-16.8	7.0	0.0	1.074	23.218
Main Wheel	[040-003]	0.434	1.633	1.633	2.09	0.266	3.168	5.216	0.816	2	20.4	1.4	-1.1	-146.2	0.0	0.0	0	20.38
Nose Wheel	[040-002]	0.332	1.249	1.249	1.223	0.266	1.854	3.053	0.365	2	7.9	0.4	-4.0	0.0	0.0	0.0	0	7.925
Nose Shock	[041-002]	2.68	0.225	0.225	0.04	11.92	1.785	1.802	0.095	1	8.3	0.0	-0.9	0.0	7.0	0.0	2.117	8.09
Nose Wheel	[040-003]	0.332	1.249	1.249	1.223	0.266	1.854	3.053	0.365	2	5.7	0.4	-1.2	0.0	0.0	0.0	0	5.702
Nose Shock	[041-003]	2.68	0.225	0.225	0.04	11.92	1.785	1.802	0.095	1	9.1	0.0	-2.0	0.0	102.9	0.0	2.117	7.041
ACESII SEA	[094-001]	2.005	5.422	3.998	5.818	0.737	37.191	46.514	11.43	1	10.2	0.0	2.5	0.0	-15.0	0.0	0.002	10.374
ACESII SEA	[094-001]	2.005	5.422	3.998	5.818	0.737	37.191	46.514	11.43	1	14.1	0.0	3.2	0.0	-15.0	0.0	0.002	14.274
APG-68 Rac	[090-002]	1.588	2.418	1.585	3.006	0.812	10.342	14.968	2.165	1	2.7	0.0	-0.6	0.0	0.0	0.0	0.825	3.501
Williams FJ	[059-000]	5.746	2.168	2.523	4.292	2.458	37.349	38.746	16.916	2	25.8	1.6	0.4	0.0	-0.7	0.0	2.884	28.653
Vert tails	[020-003]	6.667	6.571	0.565	2.13	4.049	57.048	59.665	8.1	2	29.8	2.7	1.5	12.0	0.0	0.0	1.997	30.301

figure 6. TAB File (small portion)

FPS	Enter analysis input parameters. For help click on column titles.						
1 METHOD & OPTIONS		2 REAL-WORLD CONSTRAINTS		3 VARIABLE EXTENTS: MIN		4 [BASELINE]	MAX
Opt Method	Carpet Plot	Maximum Length	45.2	T/W : Min=	0.784	[.98] Max=	1.176
Meas. Of Merit	Wo	Minimum Diameter	5.5	W/S : Min=	44.84	[56.05] Max=	67.27
RubberEngine	No	Maximum Span	32.078	A : Min=	2.8	[3.5] Max=	4.2
Calc Trim Drag	Yes	Check Pitchup	No	Sweep : Min=	30.4	[38] Max=	45.6
Recalc C (We)	No	NetDesignVol	No	Taper : Min=	0.2	[.25] Max=	0.3
%Amax Wing/Tot	0.0	Engine In Fus	No	t/c : Min=	0.048	[.06] Max=	0.072
(n/a)	0.0	Eng Fills Back	No	Fus l/d: Min=	0.8	[8.2182] Max=	1.2
(n/a)	0.0	(n/a)	0.0	CL-dsgn: Min=	0.32	[.4] Max=	0.48

figure 7. Optimizer Input Grid

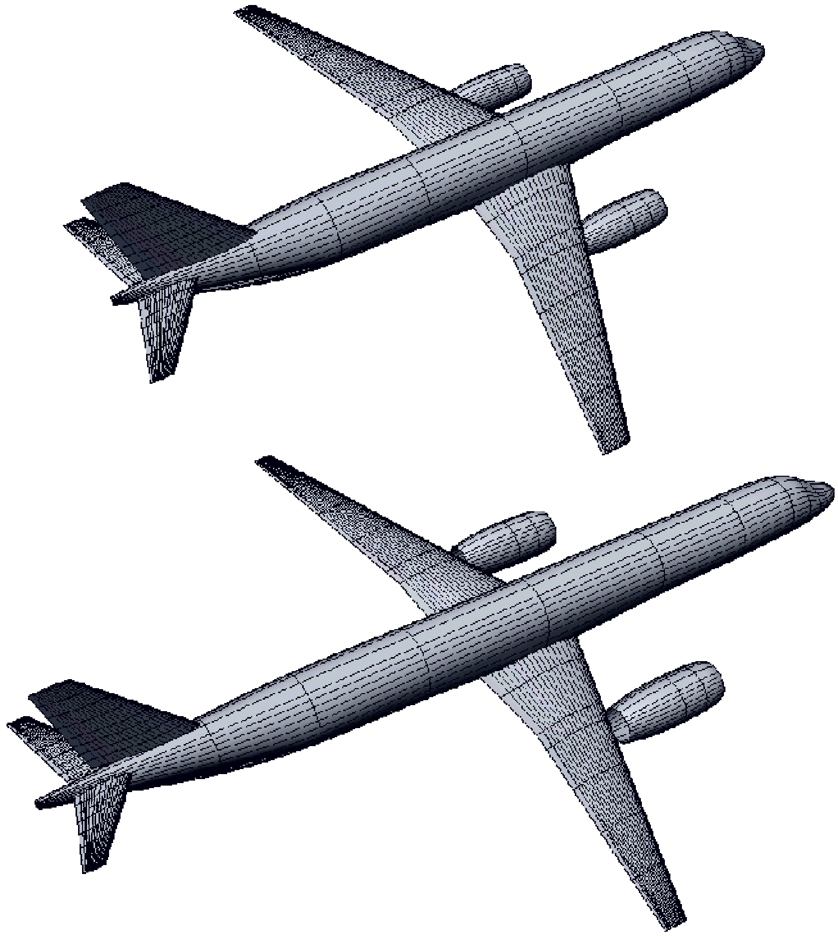


figure 8.   Automatic Redesign Base On Optimization Results

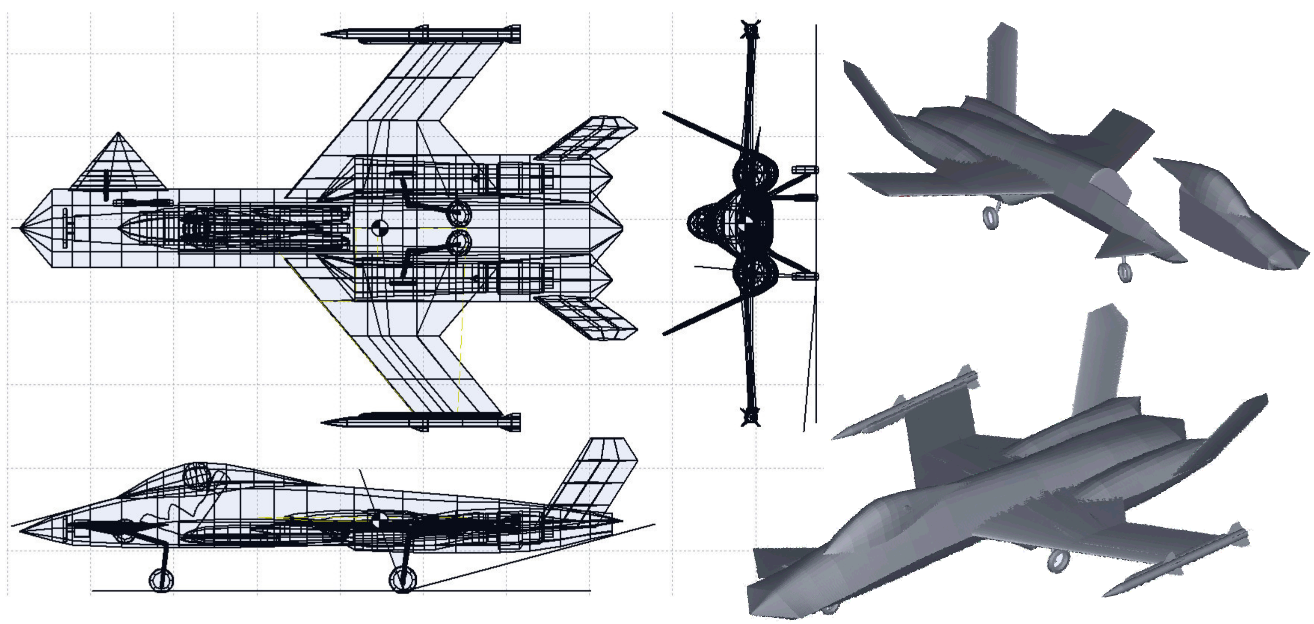


figure 9.   Design Sample – Initial Layout

Component	SAWE8 Code	Length	Width	Height	A-max	l/d-equiv.	Total Surface Area	SurfArea+ Ends	Total Volume	# comp	X	Y	Z	Roll	Pitch	Yaw	Xcentroid	Xc-global
Fuselage	[031-000]	36.299	4.714	4.04	13.16	8.868	406.587	406.588	318.584	1	0	0	0	0	0	0	16.863	16.863
Wing	[002-000]	9.45	13.247	1.079	9.311	2.744	293.353	304.129	60.764	1	20.24	0	-0.005	3	0	0	4.695	2.144
Williams FJ-4	[059-000]	5.746	2.168	2.523	4.292	2.458	37.349	38.746	16.916	2	27.26	3.01	-0.635	0	-0.725	0	2.884	30.145
Nacelle	[045-001]	17.841	2.934	2.748	5.172	6.953	128.778	128.834	66.855	2	20.21	2.28	-2.148	0	0	0	7.318	27.528
Vert Tails	[020-004]	5.933	6.277	0.222	0.528	7.239	42.004	42.686	2.853	2	33.574	4.186	-0.615	25	0	0	2.679	34.008
AIM-120c	[158-000]	12.017	1.514	1.514	0.269	20.524	29.184	29.453	2.97	2	18.132	11.711	-0.62	-44	-1	0	6.475	24.605
RightWing Ca	[020-002]	3.615	6.024	0.361	1.393	2.715	23.715	25.107	1.696	1	4.939	-2.272	-0.426	-10	0	0	-0.888	5.576
Canard Truni	[020-999]	1.87	0.275	0.275	0.059	6.805	1.326	1.358	0.077	1	5.228	-3.51	-0.643	-10	0	0	1.106	5.228
LauncherRail	[031-000]	8.595	0.309	0.507	0.151	19.61	12.628	12.779	1.249	2	20.371	11.3	-0.664	1	-1	0	4.454	24.825
APG-68 Rada	[090-002]	1.588	2.418	1.585	3.006	0.812	10.342	14.968	2.165	1	2.676	0	-0.674	0	0	0	0.825	3.501
ACESII SEAT	[094-001]	2.005	5.422	3.998	5.818	0.737	37.191	46.514	11.43	1	10.682	0	2.48	0	0	-90	0.002	10.269
Canopy	[031-001]	12.365	2.574	2.205	2.565	6.842	61.151	61.157	13.862	1	6.552	0	1.598	0	0	0	4.394	10.946
Nose Wheel	[040-002]	0.381	1.436	1.436	1.618	0.266	2.452	4.037	0.556	1	8.565	-1.523	-3.819	0	0	0	0	8.565
Nose Shocks	[041-002]	2.68	0.225	0.225	0.04	11.92	1.785	1.802	0.095	1	8.989	-1.523	-0.747	0	7	0	2.117	8.731
Nose Shocks	[041-003]	2.68	0.225	0.225	0.04	11.92	1.785	1.802	0.095	1	9.746	-1.523	-1.877	0	106.88	0	2.117	7.72
Main Wheel (	[040-001]	0.434	1.633	1.633	2.09	0.266	3.168	5.216	0.816	2	23.081	3.22	-3.77	0	0	0	0	23.081
Gear Leg Sho	[041-001]	3.22	0.263	0.415	0.086	9.755	2.589	2.683	0.166	2	23.37	1.734	-1.555	-26.3	7	0	0.952	23.265
Main Wheel U	[040-003]	0.434	1.633	1.633	2.09	0.266	3.168	5.216	0.816	2	26.454	0.881	-0.708	-101.2	-30.5	0	0	26.454
GBU-32 Mk83	[158-000]	9.95	1.274	1.274	1.07	8.527	33.237	33.325	7.641	2	9.847	0.753	-1.046	-45	0	0	4.805	14.652
GBU-39 Sma	[158-000]	5.9	0.6	0.6	0.333	9.056	10.896	11.136	1.597	2	13.969	1.023	-0.706	0	0	0	3.359	17.329
Weapons Bay	[031-009]	10.544	3.093	1.404	3.402	5.066	82.38	89.12	35.605	1	9.577	0	-1.006	0	0	0	5.245	14.822
GBU-39 Sma	[158-000]	5.9	0.6	0.6	0.333	9.056	10.893	11.133	1.597	1	13.969	0	-0.706	0	0	0	3.359	17.329
GBU-39 Sma	[158-000]	5.9	0.6	0.6	0.333	9.056	10.893	11.133	1.597	2	9.722	0.51	-1.309	0	0	0	3.359	13.081
Nose Wheelu	[040-002]	0.381	1.436	1.436	1.618	0.266	2.452	4.037	0.556	1	6.354	-1.523	-0.819	0	0	0	0	6.354
Inlet Duct	[055-000]	7.453	2.286	2.243	2.451	4.219	41.921	46.527	17.326	2	22.667	3.111	-0.617	0	0	0	1.359	24.026
WingBox	[070-000]	11.272	6.862	1.044	2.883	5.883	156.439	160.329	39.519	1	20.24	0	-0.005	3	0	0	4.317	22.867
Gear Leg Sho	[041-001]	3.22	0.263	0.415	0.086	9.755	2.589	2.683	0.166	2	23.839	1.438	-1.061	-26.3	-100.5	37.5	0.952	24.759
Kestrel LowAl	[059-000]	3.874	2.374	2.374	4.42	1.633	19.49	23.999	7.19	1	31.463	0	0	0	-1	0	2.39	33.852
Rocket Modu	[031-002]	6.485	2.346	2.349	4.316	2.766	46.265	52.567	26.225	1	28.979	0	0.059	0	0	0	2.961	31.94
LOX Tank	[071-000]	2.561	2.155	2.155	3.641	1.189	16.06	16.06	6.579	1	29.866	0	0.019	0	0	0	0.203	30.069
Weapons Bay	[031-009]	6.558	3.093	1.404	3.402	3.151	51.255	57.996	22.16	1	9.577	0	-1.006	0	0	0	7.25	16.827
Fuselage Fue	[070-000]	15.538	4.714	2.407	7.366	5.073	158.481	170.059	80.668	1	0	0	0	0	0	0	20.023	20.023
Fuselage-Cro	[031-000]	35.263	4.714	3.984	13.122	8.627	330.837	330.839	214.713	1	0	0	0	0	0	0	20.978	20.978
Fuselage-For	[031-000]	13.264	3.553	4.038	11.024	3.54	134.888	145.912	100.05	1	0	0	0	0	0	0	8.284	8.284
PiTail	[020-001]	10	10.994	0.517	1.789	6.625	105.212	107.014	10.079	1	33.998	0	4.675	0	0	0	2.983	-0.807

figure 10.   TAB File

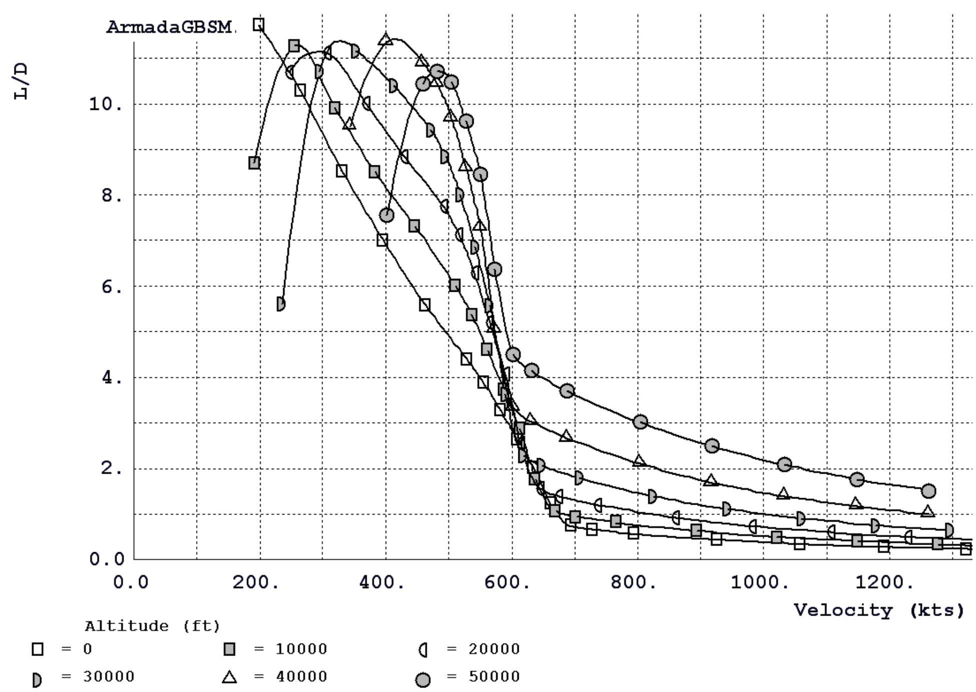


figure 11.   Aerodynamic Results

STRUCTURES GROUP	3406.5	EQUIPMENT GROUP	1989.6
Wing	718.4	Flight Controls	433.2
Horiz. Tail	36.9	Instruments	90.6
Vert. Tail	293.5	Hydraulics	183.5
Fuselage	1492.9	Electrical	445.7
Main Lndg Gear	433.4	Avionics	433.4
Nose Lndg Gear	107.8	Furnishings & Misc	217.6
Engine Mounts	46.3	Air Conditioning	181.7
Firewall	0	Handling Gear	3.8
Engine Section	24.9	APU installed	0
Air Induction	252.4		
		Misc Empty Weight	400
PROPULSION GROUP	1636.4	We-Allowance 5.0%	371.6
Engine(s)	1300	TOTAL WEIGHT EMPTY	7804.1
Tailpipe	34.1		
Engine Cooling	0	USEFUL LOAD GROUP	4195.9
Oil Cooling	69.2	Crew	220
Engine Controls	37	Fuel	3070.9
Starter	18.7	Oil	50
Fuel System	177.5	Payload	855
		TAKEOFF GROSS WEIGHT	12000
		We/Wo	65.00%
		Wf/Wo	25.60%

figure 12. Weights Results

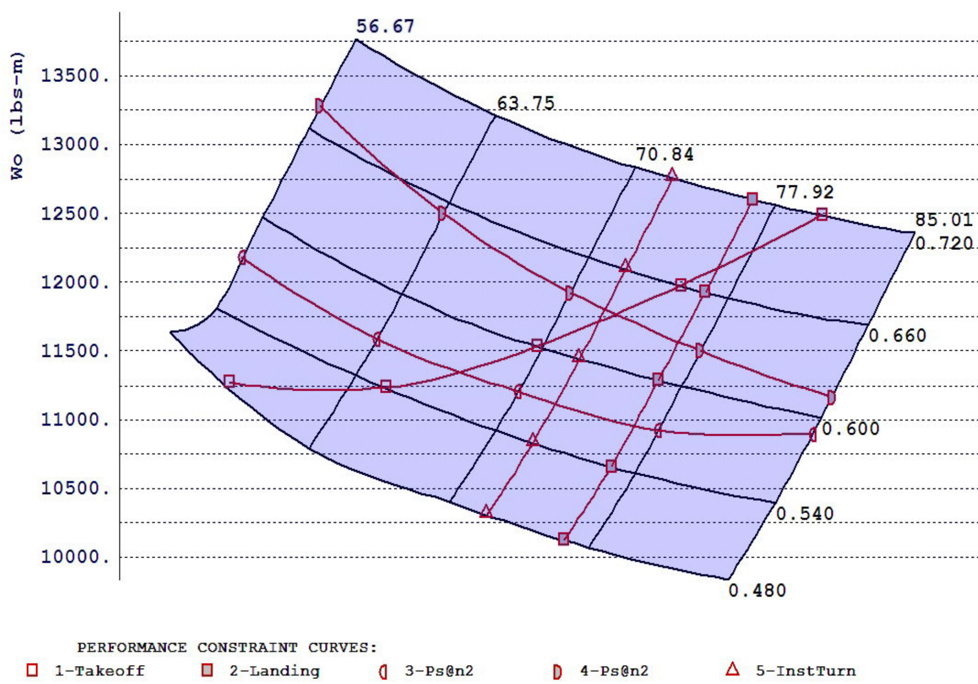


figure 13. Classic Carpet Plot

	Minimum	Baseline	Maximum	Best
T/W	0.4	0.6	0.8	0.6032
W/S	50	70.838	90	69.683
ASPECT	2.4	3	3.6	3.6
SWEEP	32	40	48	33.016
TAPER	0.16	0.2	0.24	0.1956
t/c	0.064	0.08	0.096	0.0899
Fus l/d	7.102	8.878	10.653	10.653
CL-dsgn	0.4	0.5	0.6	0.4
Sized Wo		11519		10906
Sized We		7586.3		7364.3
Sized Wf		2807.8		2416.9

Perf:	Required	Baseline		Best
Takeoff	2500	2507.6		2466.7
Landing	3200	3035.7		3003.7
Ps@n	0	6.655		23.346
Ps@n	0	-9.783		5.883
InstTurn	12	12.309		12.517

figure 14. Genetic Algorithm Optimization

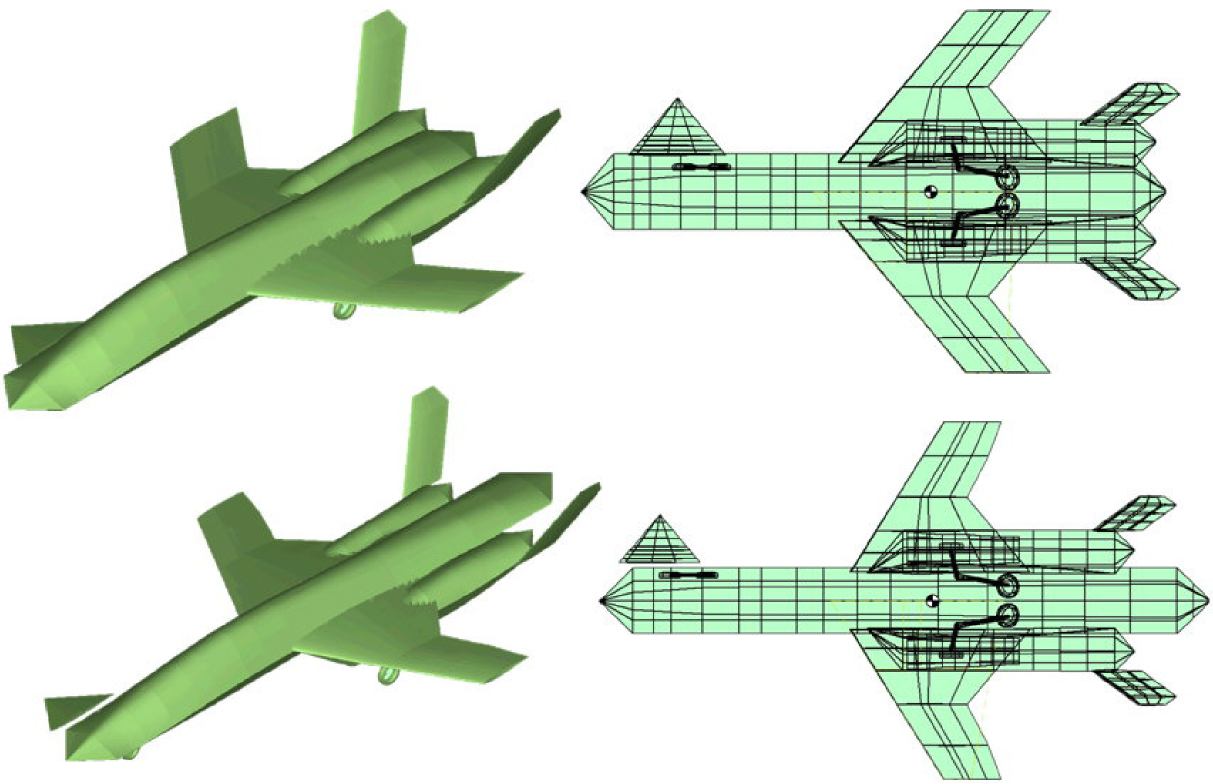


figure 15. Optimization-Revised Layout

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