**RDS\textsuperscript{win} - Integrated Windows Software for Aircraft Design, Analysis, & Optimization**

- Aircraft design, analysis, & optimization based on real industry methods and decades of personal experience, not a few equations from someone else’s book
- 25+ years of evolutionary development
- Integrated CAD, aerodynamics, weights, propulsion (jet & prop), stability & control, sizing, range, performance, & cost analysis.
- Switches between MKS and FPS
- Student & Professional versions in use world-wide
- Professional version adds automated trade studies, MDO/multivariable optimizer, greater accuracy, fully-lofted surface geometry, IGES CAD output, & numerous other “Design Pro” features

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RDS\textsuperscript{win} - Overview

• RDS\textsuperscript{win} allows taking an aircraft design from first conceptual layout through functional analysis, leading to performance, range, weight, and cost results.

• By automating the “grunt work” of vehicle analysis, RDS\textsuperscript{win} makes enough time for the student to truly learn design, and for the design professional to do a wide range of initial trade studies before the first design concept is released to other groups.

• All-new, all-original computer code (even the CAD module)

• True Windows\textsuperscript{*} Application, with pulldown menus, popup boxes, fonts, graphics, dialog boxes, clipboard read/write, Undo/Redo, and more

• RDS\textsuperscript{win} outputs analysis results and program data to popup boxes, text files, Windows printers, or directly to your spreadsheet, word processor, or internet browser.

• Powerful & flexible, with ~600 pulldown menu commands and ~100 submenus, plus on-screen buttons and hot keys

(*runs perfectly in 32- or 64-bit Windows)
AIRCRAFT DESIGN: A Conceptual Approach

Practical Working Knowledge of Aircraft Design ....As It Is Actually Performed

Overview of the Whole Design Process
• Design Layout
• Systems Integration
• Aircraft Analysis, Sizing, Performance, & Cost
• Optimization & Trade Studies
• Complete design examples

Award-winning Best Seller

60,000+ copies sold

available at http://www.aircraftdesign.com
Main Screen with Pulldown Menu & Module Buttons
The main program page of \( \text{RDS}^{\text{win}} \) looks like this, and you can click on the boxes to go to those modules.

Or navigate using the pulldown JumpTo menu, or use the pulldown File-Open, or start RDS by clicking on an RDS file, or......
RDS\textsuperscript{win}: A KEY PHILOSOPHY!

The User is in Charge - Answers do NOT flow down automatically!

• AIRCRAFT DATA FILE acts like a filing cabinet which you fill with aero, weights, and propulsion information on your design. This information then gets used for sizing, range, performance, trade studies, and optimization.

• This permits & almost forces the user to review the analysis results before using it for anything important.

• This also allows the mixing of data sources for calculations:
  - RDS analysis
  - Wind tunnel
  - CFD & FEM
  - Other analysis
  - Test data
RDS Can Be Used For All Sorts of Aircraft and Spacecraft

- Advanced Fighter
- Reusable Launch Vehicle
- Civil Transport
- General Aviation
- Tactical UAV
- Dynamic Lift Airship
Ideal for Concept Alternative Design Studies

- Open Rotor
  - NASAWLD1.DSN
- Open Rotor
  - NASAWL1d.DSN
- Shielded Open Rotor
  - NASAWL1a.DSN
- Tandem Open Rotor
  - NASAWL1c.DSN
- Forward Swept
  - NASAWLD2.DSN
- Joined Wing
  - NASAWLD3a.DSN
- Joined/Braced Wing
  - NASAWLD3.DSN
- Blended Wing Body
  - NASAWL4b.DSN
- Oblique Wing
  - NASAWLD5.DSN
- Tandem Wing
  - NASAWLD6.DSN
- Box Wing
  - NASAWLD7.DSN
- Twin Fuselage
  - NASAWLD8.DSN
- Tailless Tandem Open Rotor
  - NASAWLD9.DSN
- Tailless Open Rotor
  - NASAWLD10.DSN
- C-Wing
  - NASAWL11.DSN
- 3-Surface
  - NASAWLD12.DSN
RDS Design Layout Module (DLM)

>35,000 lines of all-new interactive CAD code

Numerous airplane-specific features and capabilities:

- Quickly Create New Fuselage, Wing/Tail, Wheel, Gear ShockStrut, Streamlined Strut, External Store, Engine, Seat, and others
- Position, Scale, Stretch, Copy, Instance, & Mirror Components
- Reshape Wings & Derived Components by Revising Ref. Wing Data
- Output Formatted Geometric Data Table (TAB)
- Output DXF, VSAERO, & RhinoCAD files (Pro only)
RDS\textsuperscript{win} has its own CAD Module - Why?

• Commercial CAD systems were developed for detail part and production design, not the fluid environment of Concept Design

• Drawbacks of commercial CAD systems:
  - Too much time to develop an initial aircraft configuration
  - Too much work to modify the configuration layout for each trade study and concept iteration
  - Too much focus on perfect local geometry, not enough on the overall concept being developed
  - Too generic – what’s an airplane?

• Discussions with vendors of existing CAD systems were not rewarding – nobody wanted to make the enhancements required to produce a tool optimized for aircraft conceptual design (“you can already do all those things…” – sure, but it takes too long!)
Aircraft Defined as Collection of Components

- Components are parts of the airplane defined in the usual vocabulary (wing, tail, fuselage, tire, engine, duct, spar, etc...)
- Components are generally individual closed shapes
- Components include geometric and non-geometric information

<table>
<thead>
<tr>
<th>Component name</th>
<th>Local axis system (X, Y, Z, Roll, Pitch, Yaw)</th>
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</thead>
<tbody>
<tr>
<td>Symmetry &amp; mirror options</td>
<td>Type of geometry (point, quartic, or quartic surface)</td>
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<td>Component pre-rotation &amp; Viewing Code</td>
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<td>Component notes (user-input)</td>
<td>Installed weight, uninstalled (or empty tank) weight</td>
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<td>Component Xcg,Ycg,Zcg</td>
<td>25 data items peculiar to type - reference wing parameters</td>
</tr>
<tr>
<td>- length, width, height</td>
<td>“Non-real” components are possible (cg symbol, tail-down angle, etc...)</td>
</tr>
</tbody>
</table>
RDS-DLM: Unique Tools For
The Unique Tasks...

- Create Component
- Get Comp from File
- Select Comp for Edit
- Shape Component
- Scale Component
- Copy Component
- Make Comp Instance
- Delete Component
- Misc Comp Options
- Comp Parameters

Create Comp:
- Fuselage
- Wing/Tail
- Wheel
- Gear Leg ShockStrut
- Streamlined Strut
- External Store
- Engine
- Seat
- Box
- Cylinder
- Sphere
- Body Of Revolution
- New Empty Comp

Comp Scaling:
- X
- Y
- Z
- YZ
- XYZ
- X/YZ (hold volume)

Wing Revision:
- Reference Area
- Aspect Ratio
- Taper Ratio
- Sweep
- Dihedral
- Airfoil t/c
- Twist & Incidence
- Replace Airfoil
- Enter LE & TE lines

...a small sampling
RDS\textsuperscript{win} Design Viewing

• RDS\textsuperscript{win} DLM “knows” what an airplane is, and makes it easy to get typical aircraft design views
  • Side, Top, Rear, and Front
  • Isometric, Orthographic, Perspective
  • Shaded, hidden-line renderings with or without wireframe lines
  • Component relative views (side, top, or rear in component’s axis system)
  • Three-Views with various orientations
  • Entire aircraft cross-section cut at component cross-section location or at a defined cut-plane
  • Stacked cross section, waterline, and buttock-plane cuts

• All viewing options are available in the pulldown menu (<1 second)
• Single stroke hot-keys available for common views (and press H for Help popup)
DLM FlyView and FlyAssemble

• RDS\textsuperscript{win} lets you “Fly” the airplane to change views and to move or rotate components, using the mouse as a “control stick” like a pilot flies an airplane.
• Views and component moves can also be done from pulldown menu or with arrow keys, and common views are available as hot keys.
Joystick FlyView and FlyAssemble

• Use your flight simulator control stick to “Fly” the airplane to change views, or to move and rotate selected components
• Single hand operation using a multifunction controller (3-axis + paddle)
• Stick motion controls translation and perspective distance (twist)
• Trigger is held for 3-axis rotations
• Paddle controls zoom (normally used for throttle)
• Buttons do instant render and cross-section cuts

Sorry, RDS\textsuperscript{win} is not a flight simulator and you cannot actually fly your airplane. But, the joystick controller is very handy for design and viewing!
Three Geometry Representations

1. Cross sections defined by Surface Points

2. Cross sections defined by SuperConics

3. Surfaces defined by SuperConics (RDS\textsuperscript{win}-Pro only)
SuperConic Parametric Curve (NURB family)

- Modified 4th degree Bezier polynomial such that middle point is on the curve, not floating in space
- Visually looks like classic conic lofting but with extra powers
- Quartic defined by five control points:
  - Two endpoints A & B
  - Two tangent control points $C_A$ & $C_B$ (conic has single C point)
  - Shoulder point S on the curve, somewhere in its middle

---

On-Screen SuperConic Shaping
(each from moving one point)
On-Screen SuperConic Shaping
(4 quick changes)
On-Screen SuperConic Shaping
(4 quick changes)
SuperConic Reshaping in Side & Top Views

- Moved Upper Centerline Points by Mouse Inputs
- Slope Control Points Automatically Moved Too
- Can move any point in side, top, or rear view
SuperConic Surface Components

• Modified 4th degree Bezier polynomials extended to surface patches using second parametric variable
• As 5 points make a SuperConic Line, so 5 SuperConic Lines make a SuperConic Surface (“patch”)

Single SuperConic Surface Patch

- SuperConic Cross Sections define longitudinal shape
- Sections 1 & 5 are patch beginning and end (A & B)
- Section 3 is patch middle line (S for “shoulder”)
- Sections 2 & 4 are “collars” ($C_A$ & $C_B$) that control slopes coming from the patch ends
SuperConic Surface Patch Is Fully Defined

• Those 5 sections fully define that patch mathematically
• Here showing 21 cross sections and 11 lines per patch

RDS\textsuperscript{win} Superconic surface components export to IGES as Entity Type 128 (Rational B-Spline Surface)
Cross Section Using Two SuperConic Patches

• 5 cross sections, each with two SuperConic curves
• Sections 1, 3, & 5 are on the surface
• Sections 2 & 4 are collars
• This is one longitudinal “patch bay”
Two Longitudinal SuperConic Patch Bays

• 9 cross sections, each with two SuperConic curves
• Two longitudinal patch bays - ie., two SuperConic
• Sections 1, 3, 5, 7, & 9 are on the surface
• Sections 2, 4, 6, & 8 are collars
• Sections 4 & 6 must be colinear for slope continuity
Two Longitudinal SuperConic Patch Bays

• Sections 1, 3, 5, 7, & 9 are on the surface
• Sections 2, 4, 6, & 8 are collars
• Sections 4 & 6 must be colinear for slope continuity
Automatic Longitudinal Smoothing

• AutoSmooth uses Method of Akima to move the slope control “collar” sections to obtain a smooth shape with longitudinal slope continuity

• Instantly, with no further inputs!
Automatic Longitudinal Smoothing

- Automatically recognizes straight longitudinal lines, and creates constant cross section or straight taper

- $2^{nd}$ derivative continuity is approximated by having adjacent collars same distance from patch end section
Non-Planar and Non-Parallel Sections

• Normally DLM components are built from parallel, planar cross sections, stacked in the X direction.

• For a canted inlet front face or similar geometry, cross section X values can be canted and warped out of perpendicular using:
  - `ComponentParameters-AllowNonParallelSections`
  - `ShapeComponent-Cant Cross Section`
  - `ShapeByLongitudinalLines`
  - `ShapeOneCrossSection (numeric X input)`
Trapezoidal Wing Shaping

StretchSections:
• Stretch in Z only
• Stretch Proportional
• Stretch in Y only
• Stretch front/back
• Stretch top/bottom
• " to ditto last stretch
Stretch Airfoil Sections – Three Options

1. Maintain t/c so thickness scales proportionally with chord, resulting airfoil is “photo-scaled”

2. Maintain actual thickness so t/c reduces as chord increases, resulting airfoil is “photo-stretched”

3. Keep thickness so t/c reduces as chord increases, but stretch only from maximum thickness point. Result is like a “glove.” Sweep of wing’s maximum thickness line is unchanged
### Reference Wing Redesign:
Parameter Revision

#### Parameters

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*…10 seconds*
Reference Wing Redesign: LE/TE/Span Input

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RDS-Pro Only
Extended SAWE8 Group Weight Statement Component Categories

Used to identify component types for weights analysis and geometry listings

- **002-000**: Ref Wing
- **002-001**: 2nd Wing
- **002-002**: Biplane Wing
- **002-003**: LEX
- **002-004**: Winglet
- **002-005**: Wing Strut
- **002-006**: Wing Struct
- **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
- **031-002**: Fairing/Pod
- **031-003**: Inlet Fairing
- **031-004**: Tailboom
- **031-005**: 2nd Fuselage
- **031-006**: Door
- **031-007**: Speed Brake
- **031-008**: Body Flap
- **031-009**: Payload Bay
- **031-010**: Bay-Other
- **031-011**: Passenger Comp
- **031-012**: Structure
- **031-999**: Fuselage-Other
- **080-999**: Misc Flt Cntrl
- **081-000**: Cockpit Cntrl
- **082-000**: Auto Flt Cntrl
- **083-000**: System Cntrls
- **084-000**: Aux Power
- **085-000**: Instruments
- **086-000**: Hydraulics
- **087-000**: Pneumatics
- **088-000**: Electrical
- **090-000**: Avionics
- **090-001**: Antenna
- **091-000**: Avionic Instrl
- **092-000**: Armament
- **094-000**: Accommodation

*(Partial listing)*
### Geometric Output File (TAB)

- Spreadsheet-formatted geometric data for reporting & analysis input
- Wing & Tail trapezoidal reference data (shown)
- Component L, W, H, $S_{wet}$, Volume, Location, Centroid, SAWE8 code, …
- Component Section Perimeters and Areas vs. X-distance
- Inputs for RDS analysis

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...10 seconds
Volume Distribution Plot

- 10 seconds
- Watertight Solid Model not required
- Broomstick for capture area effects

Volume Distribution Plot: NAS2BAS2

Cross-Section Area (sq-ft)

Total Volume: 17329
Maximum Cross-section Area: 222.24
at X: 74.3

X-distance from Origin (ft)
- CreateNew (design)
- Component-NewWing/Tail
- Component-NewComponent
- Fuselage

- ViewRelative-Front (of wing)
- ShapeComponent-MoveSections
- FlyAssemble

- FlyAssemble

- FlyAssemble

- FlyAssemble
- NewComponent-Canopy
- Component-NewWing/Tail
- FlyAssemble
- Shape (various)

2 hours

- ShapeOneCrossSection
- ShowSliceThroughAllComps

- View-SliceViews-CrossSections
- GetCompFromFile (ground)
- NewComponent-wheel
- NewComponent-strut
- FlyAssemble, Scale, Stretch,...

- GetCompFromFile (cut plane)
- FlyAssemble

- View-SliceWithCutPlane

- View-SliceViews-ButtockPlane

3.5 hours
RDS ANALYTICAL METHODS

- Classical aerodynamics methods
  - DATCOM lift curve & max lift
  - Component buildup for parasitic drag
  - Leading-edge suction (drag-due-to-lift)
  - Empirical transonic estimations
- Longitudinal stability & trim
- Statistical component weights
- Jet, Turboprop, and Piston-Prop
- Full mission sizing, range, & performance analysis capabilities
- Development & procurement cost, yearly O&S costs
- “Canned” trade studies - Cdo, range-payload, cost,…
- Carpet Plots & Multivariable Optimizer

Most methods are described in Raymer’s text “AIRCRAFT DESIGN: A Conceptual Approach”
RDS ANALYTICAL METHODS

• Most methods are described in Dr. Raymer’s classic text *AIRCRAFT DESIGN: A Conceptual Approach*, now in its 5th edition

• With 50,000 copies sold, it is the premier textbook in the world today for learning aircraft conceptual design

• Well-worn copies are commonly seen in industry and government design offices
AERODYNAMICS RESULTS
# TYPICAL WEIGHTS RESULTS

**FIGHTER/ATTACK GROUP WEIGHT STATEMENT: MKS Units**

<table>
<thead>
<tr>
<th>STRUCTURES GROUP</th>
<th>2053.1</th>
<th>EQUIPMENT GROUP</th>
<th>1391.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing</td>
<td>662.0</td>
<td>Flight Controls</td>
<td>297.4</td>
</tr>
<tr>
<td>Horiz. Tail</td>
<td>127.2</td>
<td>Instruments</td>
<td>55.7</td>
</tr>
<tr>
<td>Vert. Tail</td>
<td>0.0</td>
<td>Hydraulics</td>
<td>77.9</td>
</tr>
<tr>
<td>Fuselage</td>
<td>713.9</td>
<td>Electrical</td>
<td>323.5</td>
</tr>
<tr>
<td>Main Lndg Gear</td>
<td>286.4</td>
<td>Avionics</td>
<td>448.9</td>
</tr>
<tr>
<td>Nose Lndg Gear</td>
<td>77.6</td>
<td>Furnishings</td>
<td>98.7</td>
</tr>
<tr>
<td>Engine Mounts</td>
<td>17.7</td>
<td>Air Conditioning</td>
<td>86.5</td>
</tr>
<tr>
<td>Firewall</td>
<td>26.7</td>
<td>Handling Gear</td>
<td>2.4</td>
</tr>
<tr>
<td>Engine Section</td>
<td>9.5</td>
<td>MISC EMPTY WEIGHT</td>
<td>453.6</td>
</tr>
<tr>
<td>Air Induction</td>
<td>132.0</td>
<td>TOTAL WEIGHT EMPTY</td>
<td>4965.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROPULSION GROUP</th>
<th>1067.9</th>
<th>USEFUL LOAD GROUP</th>
<th>2509.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine(s)</td>
<td>688.1</td>
<td>Crew</td>
<td>99.8</td>
</tr>
<tr>
<td>Tailpipe</td>
<td>0.0</td>
<td>Fuel</td>
<td>2006.1</td>
</tr>
<tr>
<td>Engine Cooling</td>
<td>78.0</td>
<td>Oil</td>
<td>22.7</td>
</tr>
<tr>
<td>Oil Cooling</td>
<td>17.2</td>
<td>Payload</td>
<td>381.0</td>
</tr>
<tr>
<td>Engine Controls</td>
<td>9.1</td>
<td>Passengers</td>
<td>0.0</td>
</tr>
<tr>
<td>Starter</td>
<td>17.9</td>
<td>Misc Useful Load</td>
<td>0.0</td>
</tr>
<tr>
<td>Fuel System</td>
<td>257.6</td>
<td>TAKEOFF GROSS WEIGHT</td>
<td>7475.2</td>
</tr>
</tbody>
</table>

**EMPTY CG= 7.2  LOADED-NO FUEL CG= 7.1  GROSS WT CG= 7.0**
PROPELLER ANALYSIS RESULTS

THRUST (kN)

ALTITUDE (m)

\[
\begin{align*}
\square &= 0 & \blacksquare &= 2500 & \diamond &= 5000 \\
\triangle &= 7500 & \blacktriangle &= 9144
\end{align*}
\]

V (km/h)
Sizing and Mission Range

• Typical Sizing Missions can be selected from a list, or you can pick mission segments from the buttons shown below. Then you are taken to an input grid to enter required information such as range, throttle setting, speed, and altitude. A complicated new mission can be created in 5 minutes or less.

• When Do Analysis is selected, the aircraft in your Aircraft Data File (DAT) is sized to the mission, or the range that your aircraft can attain is calculated. RDS\textsuperscript{win} then shows a full printout.

• In RDS\textsuperscript{win}-Pro, automatic trade studies such as range vs. SFC can be done instantly. Students must do such trades “manually,” using RDS to calculate the effect of changes in the parametric variable. With RDS this only takes 5-10 minutes.
# SIZING & RANGE CALCULATION

Sample: Ohio Airship Dynalifter

<table>
<thead>
<tr>
<th>MISSION SEGMENT</th>
<th>MISSION SEGMENT WEIGHT</th>
<th>Wi/WO</th>
<th>FUEL BURN (lbs-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRACTION</td>
<td></td>
<td>SEGMENT</td>
<td>TOTAL</td>
</tr>
<tr>
<td>1 TAKEOFF SEGMENT</td>
<td>0.9990</td>
<td>0.9990</td>
<td>227.2</td>
</tr>
<tr>
<td>2 TAKEOFF SEGMENT</td>
<td>0.9992</td>
<td>0.9982</td>
<td>177.2</td>
</tr>
<tr>
<td>3 CLIMB and/or ACCEL.</td>
<td>0.9935</td>
<td>0.9917</td>
<td>1453.0</td>
</tr>
<tr>
<td>4 CRUISE SEGMENT</td>
<td>0.5401</td>
<td>0.5356</td>
<td>102625.5</td>
</tr>
<tr>
<td>5 DESCENT ANALYSIS</td>
<td>0.9990</td>
<td>0.5351</td>
<td>125.8</td>
</tr>
<tr>
<td>6 LOITER SEGMENT</td>
<td>0.9945</td>
<td>0.5321</td>
<td>667.0</td>
</tr>
<tr>
<td>7 CLIMB and/or ACCEL.</td>
<td>0.9959</td>
<td>0.5299</td>
<td>493.3</td>
</tr>
<tr>
<td>8 CRUISE SEGMENT</td>
<td>0.9595</td>
<td>0.5084</td>
<td>4833.8</td>
</tr>
<tr>
<td>9 DESCENT ANALYSIS</td>
<td>0.9989</td>
<td>0.5079</td>
<td>123.0</td>
</tr>
<tr>
<td>10 LOITER SEGMENT</td>
<td>0.9949</td>
<td>0.5053</td>
<td>587.3</td>
</tr>
<tr>
<td>11 LANDING SEGMENT</td>
<td>0.9990</td>
<td>0.5048</td>
<td>113.7</td>
</tr>
</tbody>
</table>

Reserved & trap : 6685.6
Total fuel : 118112.4

<table>
<thead>
<tr>
<th>MISSION SEGMENT</th>
<th>KNOTS AT</th>
<th>RANGE</th>
<th>LOITER TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seg. 4 CRUISE</td>
<td>100.0 kts at 10000.0 ft</td>
<td>2880.5 nmi</td>
<td>0.3 hrs</td>
</tr>
<tr>
<td>Seg. 6 LOITER</td>
<td>70.0 kts at 2000.0 ft</td>
<td>200.0 nmi</td>
<td>0.3 hrs</td>
</tr>
<tr>
<td>Seg. 8 CRUISE</td>
<td>75.0 kts at 10000.0 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seg. 10 LOITER</td>
<td>60.0 kts at 2000.0 ft</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL RANGE = 3080.5
TOTAL LOITER TIME = 0.66

FUEL WEIGHT = 118094.3
EMPTY WEIGHT = 250637.7

USEFUL LOAD (less Wf) = 81,268.0
AIRCRAFT GROSS WEIGHT = 450000.0

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IMPACT OF RANGE ON SIZED WEIGHT

Wo and We (lbs-m)  Wo v.s. RANGE (nm)  Project: GA-DPR

Baseline Range (nmi) = 600  RANGE (nm)

RDS-Pro Only
RATE OF CLIMB

ALTITUDE (ft)  AB (OR MAX POWER)  Mach Number
\(\square = 0\)  \(\blacksquare = 10000\)  \(\lozenge = 20000\)
\(\triangledown = 30000\)  \(\blacklozenge = 36152\)  \(\circ = 50000\)
RDS COST ANALYSIS: CHECK CASE F-16

RAND DAPCA IV MODEL

Investment Cost Factor = 1.15
DAPCA Fudge Factor = 1.25

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>21,093.</td>
<td>$1,641,001</td>
</tr>
<tr>
<td>Tooling</td>
<td>12,373.</td>
<td>$988,592</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>65,853.</td>
<td>$4,344,331</td>
</tr>
<tr>
<td>Quality Control</td>
<td>10,948.</td>
<td>$798,663</td>
</tr>
<tr>
<td>Development Support</td>
<td></td>
<td>$289,498</td>
</tr>
<tr>
<td>Flight Test</td>
<td></td>
<td>$164,698</td>
</tr>
<tr>
<td>MFG Materials</td>
<td></td>
<td>$2,049,986</td>
</tr>
<tr>
<td>Engine Prod (ea)</td>
<td></td>
<td>$3,300</td>
</tr>
<tr>
<td>Avionics (per plane)</td>
<td></td>
<td>$3,000</td>
</tr>
<tr>
<td>Total Hours</td>
<td>110,267</td>
<td>$15,946,769</td>
</tr>
</tbody>
</table>

COST PER AIRCRAFT: $17,719
PRICE PER AIRCRAFT: $20,376

Wikipedia says F-16C/D price was $18.8 million in 1998 dollars
### RDS Carpet Plot & MDO

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Baseline</th>
<th>Maximum</th>
<th>Best</th>
</tr>
</thead>
<tbody>
<tr>
<td>T/W</td>
<td>0.5808</td>
<td>0.726</td>
<td>0.8712</td>
<td>0.6223</td>
</tr>
<tr>
<td>W/S</td>
<td>61.02</td>
<td>76.271</td>
<td>91.53</td>
<td>68.284</td>
</tr>
<tr>
<td>ASPECT</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3.</td>
</tr>
<tr>
<td>SWEEP</td>
<td>38.4</td>
<td>48.</td>
<td>57.6</td>
<td>39.314</td>
</tr>
<tr>
<td>TAPER</td>
<td>0.096</td>
<td>0.12</td>
<td>0.144</td>
<td>0.112</td>
</tr>
<tr>
<td>t/c</td>
<td>0.036</td>
<td>0.045</td>
<td>0.054</td>
<td>0.054</td>
</tr>
<tr>
<td>Fus l/d</td>
<td>11.08</td>
<td>13.846</td>
<td>16.62</td>
<td>16.532</td>
</tr>
<tr>
<td>CL-dsgn</td>
<td>0.16</td>
<td>0.2</td>
<td>0.24</td>
<td>0.2222</td>
</tr>
<tr>
<td>Sized Wo</td>
<td></td>
<td>45004</td>
<td></td>
<td>37208</td>
</tr>
<tr>
<td>Sized We</td>
<td></td>
<td>23870</td>
<td></td>
<td>20287</td>
</tr>
<tr>
<td>Sized Wf</td>
<td></td>
<td>18004</td>
<td></td>
<td>13791</td>
</tr>
<tr>
<td>InstTurn</td>
<td>20.</td>
<td>25.819</td>
<td></td>
<td>27.918</td>
</tr>
<tr>
<td>Ps@n=5</td>
<td>0.0</td>
<td>53.072</td>
<td></td>
<td>115.32</td>
</tr>
<tr>
<td>Ps@n=1</td>
<td>0.0</td>
<td>30.679</td>
<td></td>
<td>44.2</td>
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<tr>
<td>Accel</td>
<td>30.</td>
<td>24.257</td>
<td></td>
<td>29.709</td>
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<tr>
<td>Takeoff</td>
<td>2000.</td>
<td>1221.3</td>
<td></td>
<td>1258.</td>
</tr>
<tr>
<td>Landing</td>
<td>2000.</td>
<td>2194.2</td>
<td></td>
<td>1964.8</td>
</tr>
<tr>
<td>PRICE k$</td>
<td></td>
<td>40547</td>
<td></td>
<td>36173</td>
</tr>
<tr>
<td>LCC k$</td>
<td></td>
<td>93953</td>
<td></td>
<td>88241</td>
</tr>
</tbody>
</table>

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MDO Results: Transport

![Graph showing MDO results for different algorithms and strategies. The graph plots Best MOM (Wo) against \( RDS^{\text{win}} \) and \# Cases. The algorithms compared are Roulette, Tourn, KillerQueen, BreederPool, and OSD. The graph includes a note indicating \( 3^8 \) less disallowed variables and a note on 8 variables.]
ROAST: 3-DOF Trajectory Simulation

“RDS Optimal AeroSpace Trajectories” or “Raymer’s POST Approximation”

Rapid simulation of aircraft flight path or rocket vertical launch

Optimal trajectories or direct user control

Time step integration of $F=ma$:

- Gravitational weight vector
- Round-Earth centrifugal force
- Staging & Orbit Circularization

Vehicle data from Aircraft Data File

- Thrust & SFC or $I_{sp}$
- Lift and Drag (Newtonian if >M6)
- Weights

User-input limits on $q$, $M$, $n_{axial}$, $n_{lateral}$

![Graph showing altitude and down range distance](image)
ROAST Trajectory Results - Pullup to Launch
RDS ANALYTICAL METHODS

• Most methods are described in Dr. Raymer’s classic text AIRCRAFT DESIGN: A Conceptual Approach, now in its 6th edition

• With 50,000 copies sold, it is the premier textbook in the world today for learning aircraft conceptual design

• Well-worn copies are commonly seen in industry and government design offices
Wow, Great Program!
– where do I get it and what does it cost?

Nice of you to say so!

- **RDS\textsuperscript{win}-Student** is available separately or bundled with Dr. Raymer’s textbook. It is fairly cheap, priced as “charity” to students and is not to be used for professional (money-making) activities. Get it at [www.aiaa.org](http://www.aiaa.org) or [www.amazon.com](http://www.amazon.com) or other retailers. Make sure the seller sends you RDS\textsuperscript{win}, not the old DOS version!

- **RDS\textsuperscript{win}-Pro** is available only from Conceptual Research Corporation. It is relatively cheap – one customer has estimated that it would take at least $100,000 per year to develop and support a similar capability in-house.

For more information see [www.aircraftdesign.com](http://www.aircraftdesign.com)

\textit{This document is not an offer to sell nor a promise of functionality nor a warrantee of any sort. RDS is delivered with a “shrink-wrap” license agreement which supersedes any other warranties, explicit, implied, or assumed.}
RDS\textsuperscript{win}-Stud vs. RDS\textsuperscript{win}-Pro

- \textbf{RDS}^\textit{win}-Student is written so students don't waste time doing calculations
- \textbf{RDS}^\textit{win}-Pro is for professionals who work in industry, government, or academia to develop and analyze new aircraft concepts. It includes:
  - SuperConic Surface Component Design (4\textsuperscript{th} degree Bezier Polynomial)
  - Break mission into small step sizes for better sizing, range, and climb accuracy
  - Find optimal cruise, loiter, and climb during sizing and range analysis
  - Do automatic sizing trade studies – drag, SFC, weight, payload, and range
  - Input and use jet engine part-power tables
  - Use alternative atmosphere models (ISO+10, etc.)
  - Calculate effects of winds on range and sizing calculations
  - Customize analysis constants and Leading Edge Suction Schedule
  - Underlay images for 3D “tracing”, allowing quick modeling of existing designs
  - Create standard NACA airfoils, and import airfoils data in common formats
  - Automatically scale design to match sizing and MDO (wings, tails, fuselage, tires, gear struts, engine, inlet, nacelle, tanks, etc…)
  - Export design layout in DXF, RhinoCAD, and VSAERO formats
  - Carpet Plots and Multidisciplinary Design Optimizer (MDO) including GA
  - ROAST trajectory code (aircraft, rocket, & launch vehicle time-step performance)

- Compiled from same source code with portions skipped by metacommand