



# Experiences Implementing a GA-Based Optimizer in an Engineering Application

**Tom Dickens**

Associate Technical Fellow

The Boeing Company

Seattle WA, USA


thomas.p.dickens@boeing.com

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## Outline

- 
- Goal Of Tutorial
  - Overview of Engineering Application, AGPS
  - Optimization Needs in AGPS
  - Framework of a GA -Based Optimizer
  - Packaging Optimizer for User Consumption
  - Current Results and Future Work
  - Conclusions
  - Q&A, Demonstration
  - References

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## Goal Of Tutorial

- **We Will Cover**
  - Our Boeing Engineering Application, for Context
  - Why We Did This
  - How We Did This
  - Results and Target Problems
  - Future Work
- **We Will Not Cover**
  - How a GA Works
  - Complete and Detailed Source Code

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## Overview of Engineering Application, AGPS

### AeroGrid and Paneling System (AGPS)

- **A Surface Geometry System**
  - Points, Grids
  - Curves, Surfaces, Solids
  - Data transfer to/from CAD.
  - Intersections and CAD functions. What it's not.
- **A Grid Generation System**
  - Structured grid
  - Unstructured Grid
  - Input to analysis codes
- **A Visualization and Post -processing System**
  - Surfaces
  - Data

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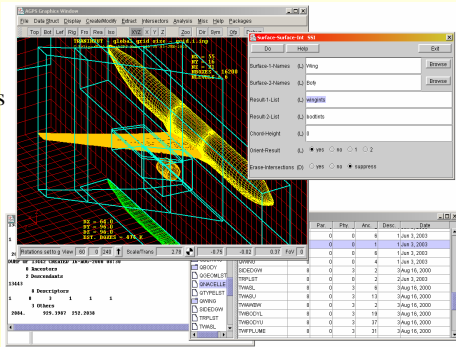


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## Overview of AGPS - Running

Graphics



Menus

Object  
Browsers

Command Line & Output

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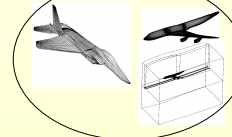


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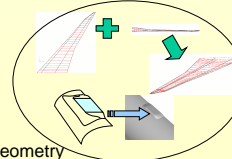
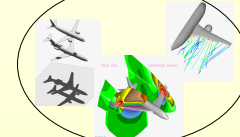
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## Overview of AGPS - Uses

Grid and Panel  
Generation



Visualization



Geometry  
Manipulation

- Customizable for specific applications
  - Journaling/Replay to automate processes
  - Customizable menu structure
  - Programming language designed for geometry manipulation
  - Library of pre-existing macros/specialized packages
  - Graphical and command-line interfaces

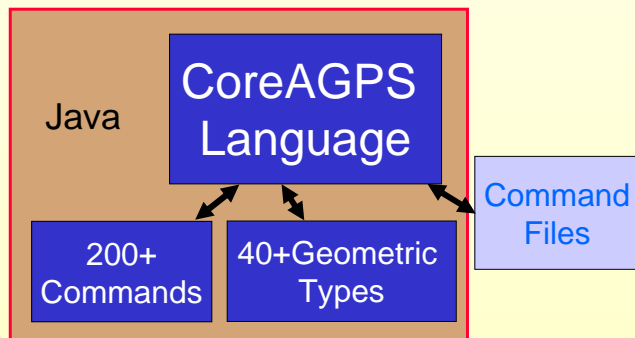
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## Overview of AGPS - Architecture



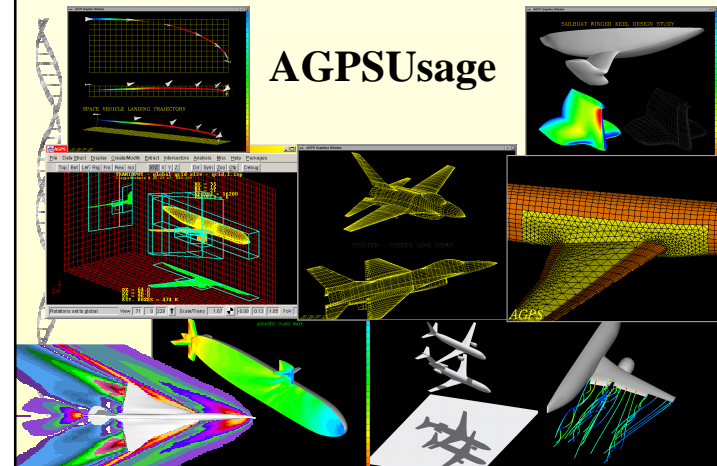
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## AGPS Usage



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## AGPS – External Marketing

- **2003 – Calmar Licensing of AGPS From Boeing**  
Calmar Research's Software Technology Group (STG) announces the launch of AGPS (licensed by Boeing).  
[http://www.calmarresearch.com/software\\_tech/agps.htm](http://www.calmarresearch.com/software_tech/agps.htm)

*For 20 years, only Boeing's top designers have had access to AGPS, considered by many in the aerospace community to be the best design tool available.*

*"Boeing is letting the genie out of the bottle," says Garvin Forrester, Lead Engineer of Calmar Research Corporation's new Software Technology Group.*

*Marketing plans call for AGPS to be offered through annual licensing agreements. Boeing provides ongoing software updates, and Calmar's Software Technology Group provides commercial support, consulting and training.*

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## Optimization Needs in AGPS

- **What Engineers Want To Generate Via Optimization:**
  - Component-to-Component Smoothing or Fillets
  - Reduced-Order Geometry (Refit to Tolerance)
  - Grids (Structured and Unstructured)
  - Geometry for Better Performance Based On:
    - CFD, FEM, Aeroelastics, Manufacturability, Cost, etc.
  - Non-Deterministic Geometric Cases
  - Multi-Disciplinary Constraints
  - Things That We Cannot Imagine or Plan For...

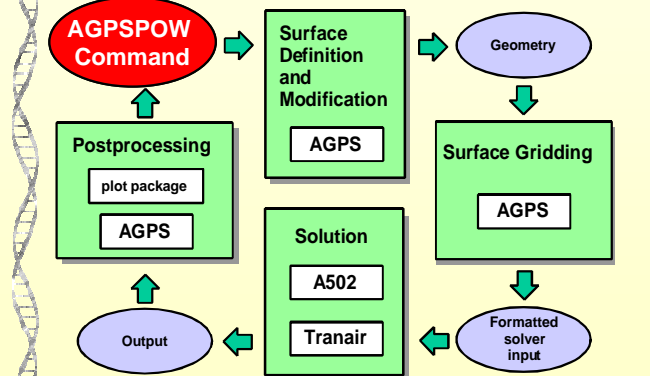
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## Automating AGPS Optimization



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## Framework of a GA -Based Optimizer - Goals

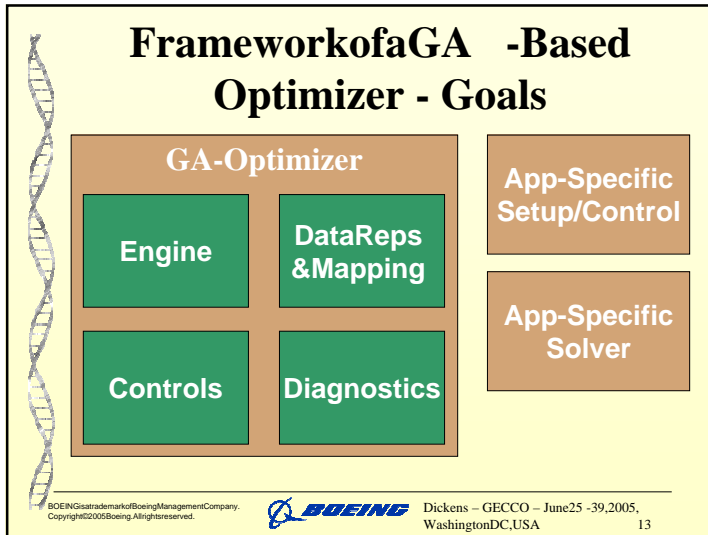
- **Written In Java**
- **Not AGPS -Specific, Usable By Others**
- **Easy To Use By:**
  - End User
  - Application Developer
- **Work With a Variety Of Data**
- **Robust**
- **Configurable**
- **Diagnostics**

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## Packaging Optimizer for End-User Consumption

- **Package Interface in User's Terms**
- **Make Defaults for Most (all) Settings**
- **Provide Feedback in User's Terms**
- **Provide Simple Working Examples**
- **Provide Cause -and- Effect Guidance on Settings** (i.e. small tolerance = long to solve, large tolerance = possible values limited)

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## Packaging Optimizer for End-User Consumption

Data Specification	
User View	GA Internal View
Data Type (integer, real)	Bit Mapping to/from Data, determines total number of GA bits and population size
Minimum and Maximum Values	
Granularity (maybe Distribution?)	
Fitness Target	Fitness Target
Maximum Time To Try	Maximum Time To Try
-none-	Internal Tracking and Tweaking of GA Operators

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## AGPS Interface to Optimizer

- **New AGPS Command – POW**
  - POWInit
  - POWParameterName MinMaxResolution
  - POWSetFitness -Target
  - [POWSetMaximum -Time]
  - POWRun
  - POWReportFitness -Value (Callback)

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## AGPSInterfacetoOptimizer – Example - Initialization

```
$targetfitness = 0.01
$res = 0.01

POW INIT FULL
POW PARAMETER REAL-LINEAR Name=X1 value=0.0 1.0 Resolution=res
POW PARAMETER REAL-LINEAR Name=Y1 value=0.0 1.0 Resolution=res
POW PARAMETER REAL-LINEAR Name=XM value=0.0 1.0 Resolution=res
POW PARAMETER REAL-LINEAR Name=YM value=0.0 1.0 Resolution=res
POW PARAMETER REAL-LINEAR Name=X2 value=0.0 1.0 Resolution=res
POW PARAMETER REAL-LINEAR Name=Y2 value=0.0 1.0 Resolution=res
POW PARAMETER REAL-LINEAR Name=DEGREE value=0.0 1.0 Resolution=1

POW SET FITNESS-TARGET Value=targetfitness
```

**Parameter Names**   **Min/Max Values**   **Resolution**

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## AGPSInterfacetoOptimizer – Example - Callback

```
CST S [(X1,Y1),(XM,YM),(X2,Y2)]
$IF DEGREE == 0
FCV C S DEGREE=CUBIC
$ELSE
FCV C S DEGREE=QUINTIC
$ENDIF

$FITNESS = ...some engineering calculation...

POW REPORT Name=#PowJobID Value=FITNESS
```

**Use Parameter Names, Unique for Each Invocation**

**Engineering Magic**

**Report Result Back To POW**

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## AGPSInterfacetoOptimizer – Example – Engineering Magic

```
$DELTASUM = 0
$FOR I=1 TO NUMPOINTS
CLO C RES= POINT-TARGETPOINTS.<I> DIST=D
$DELTASUM = DELTASUM + D
$ENDDO

LEN C OUTPUT=CURVELENGTH

$FITNESS = DELTASUM * (CURVELENGTH + 0.5)
```

- **Use Sum of Distances from Curve to each Point, and also reward smaller Curves. These two terms MUST be balanced.**

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## AGPSInterfacetoOptimizer – Example – Run & Report

```
$for i=1 to 10000
! POW RUN will set this if done
$powfitness = targetfitness * 2
POW RUN name=PowJob2.agps value=100
$if powfitness <= targetfitness
$write 'Target fitness reached'
$break
$endif
$enddo

POW REPORT
```

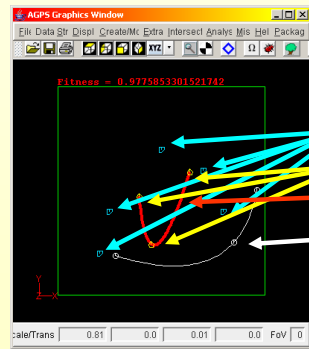
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## POWResults – AGPSDisplay



- 5Targetpoints
- 3CurvePointsfromParameters
- Red:BestGA -SolutionThusFar
- White:CurrentGA -Solution

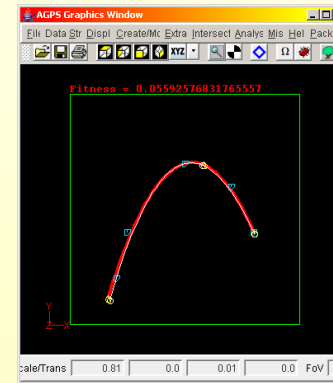
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## POWResults – 3Points



WatchResults  
At10Times

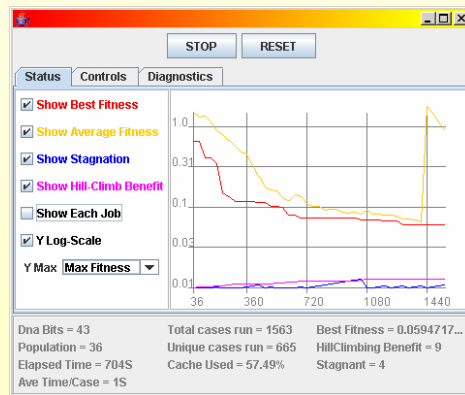
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## POWStatus – 1563Cases



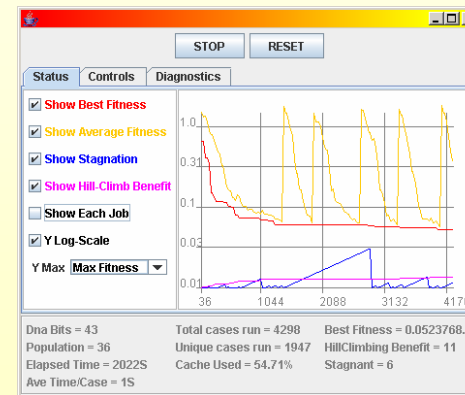
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## POWStatus – 4298Cases



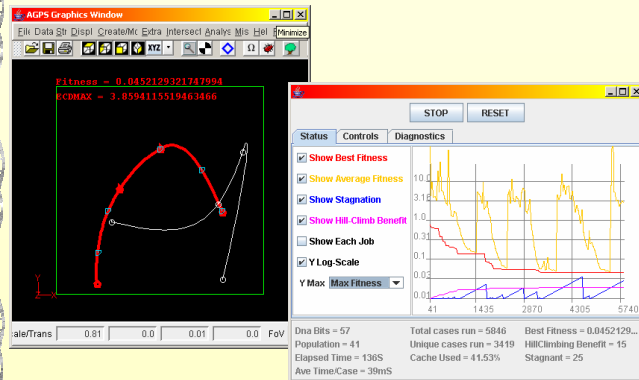
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## POWResults – 4Points



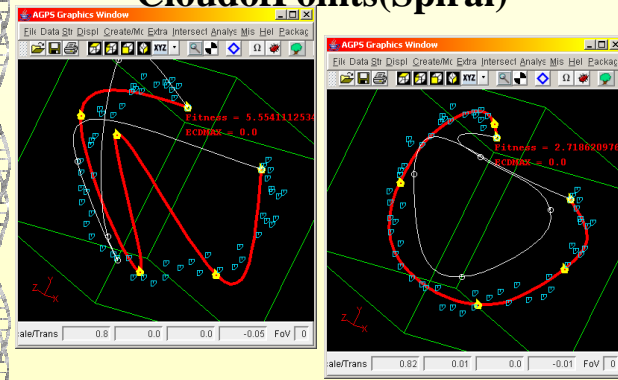
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## POWResults – 3DCurveThrougha CloudofPoints(Spiral)



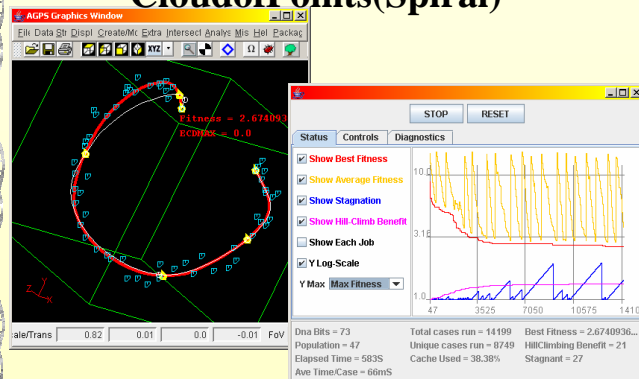
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## POWResults – 3DCurveThrougha CloudofPoints(Spiral)



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## CurrentResultsandFutureWork

- POWWorksWell!
- WillBeInNextAGPSRelease
- InterestedtoSeeingHowEngineersUseIt
- RefinePOWInternalLogicFor:
  - Speed,Ease -Of-Use,DynamicAdjustments
- ApplyGA -EnginetoOtherEngineering Applications (remember,itisNOTAGPS -specific)

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## Conclusions

- WeHaveEnoughComputePowerto WorkInterestingEngineeringProblems
- PackagingOptimizerforHands -OffUse ittheKeyChallenge,because...
- UsersWantaBlack -BoxOptimizer
- CachingGA -SolutionsHasaSignificant BenefitforLongSolutions
- JavaWorksWell,ItIsNOTthe PerformanceConcern

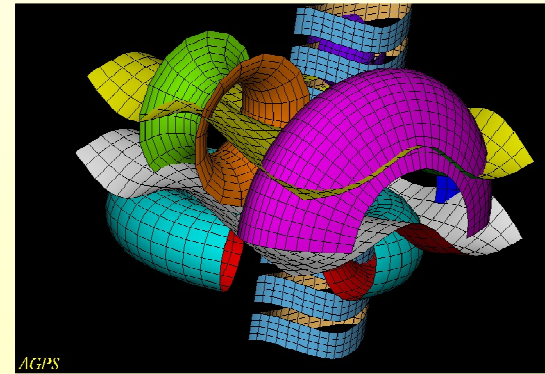
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## Q&A,Demonstration



AGPS

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## References

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- **Toms'Publications (manyonAGPS)**
  - <http://tomdickens.com/papers.html>

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