SUPPORTING
EUROPEAN
AVIATION

OVERVIEW of BADA

EUROCONTROL's Base of Aircraft Data

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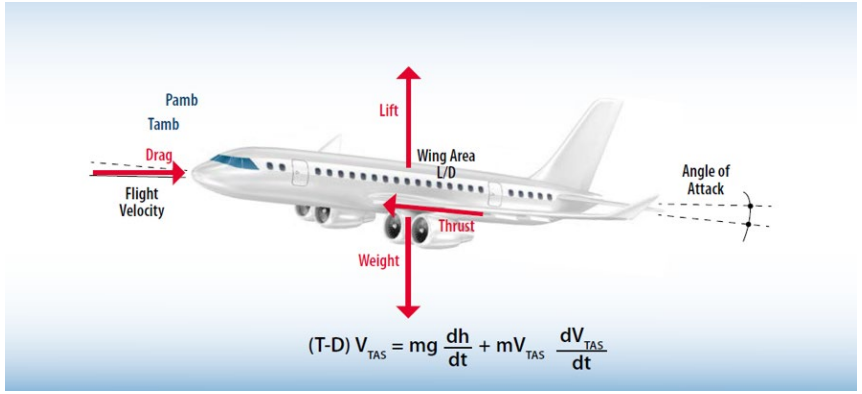
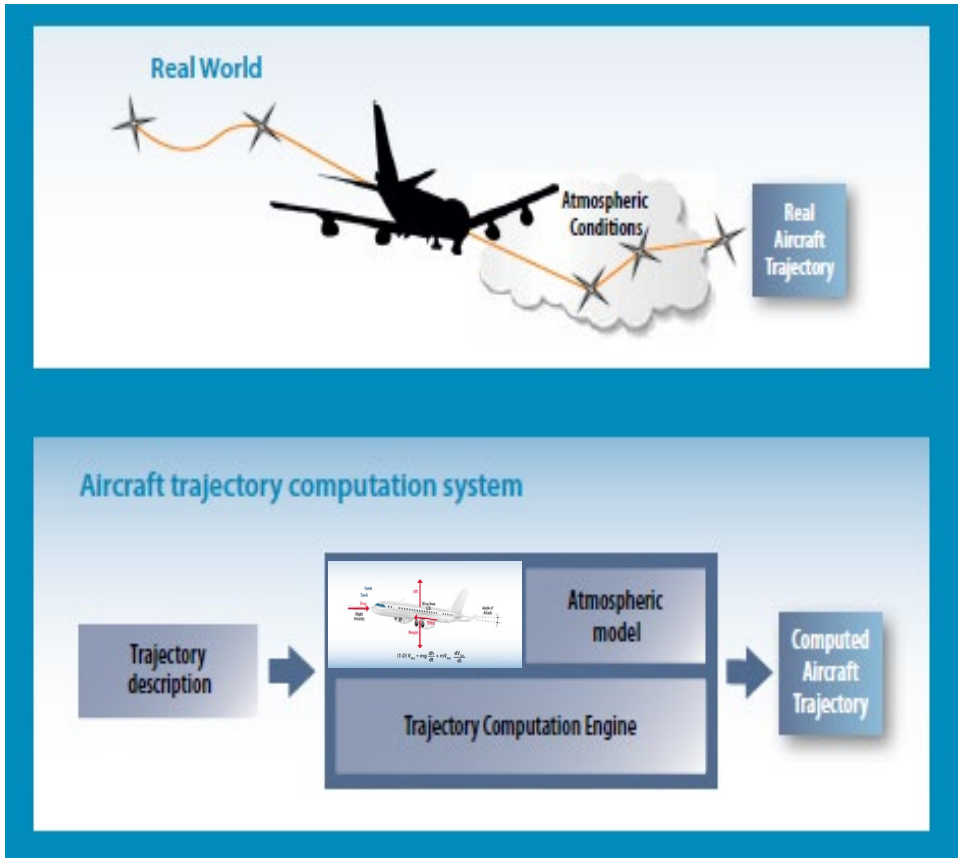
8 June 2024

CONSORTIUM COORDINATOR sesar DEPLOYMENT MANAGER
FOUNDING MEMBER sesar JOINT UNDERTAKING
NETWORK MANAGER

What is BADA?

- Aircraft Performance Model (APM)
- Designed for simulation and prediction of aircraft trajectories for purposes of ATM research and operations





- Used by EUROCONTROL and provided to ATM community worldwide

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Input data for modelling process

- BADA models developed from various public and aircraft manufacturer's proprietary data:
  - Jane's All the World's aircraft
  - Aircraft flight and operating manuals
  - Performance software
- Flight recordings or radar tracks
  - Used as complementary data

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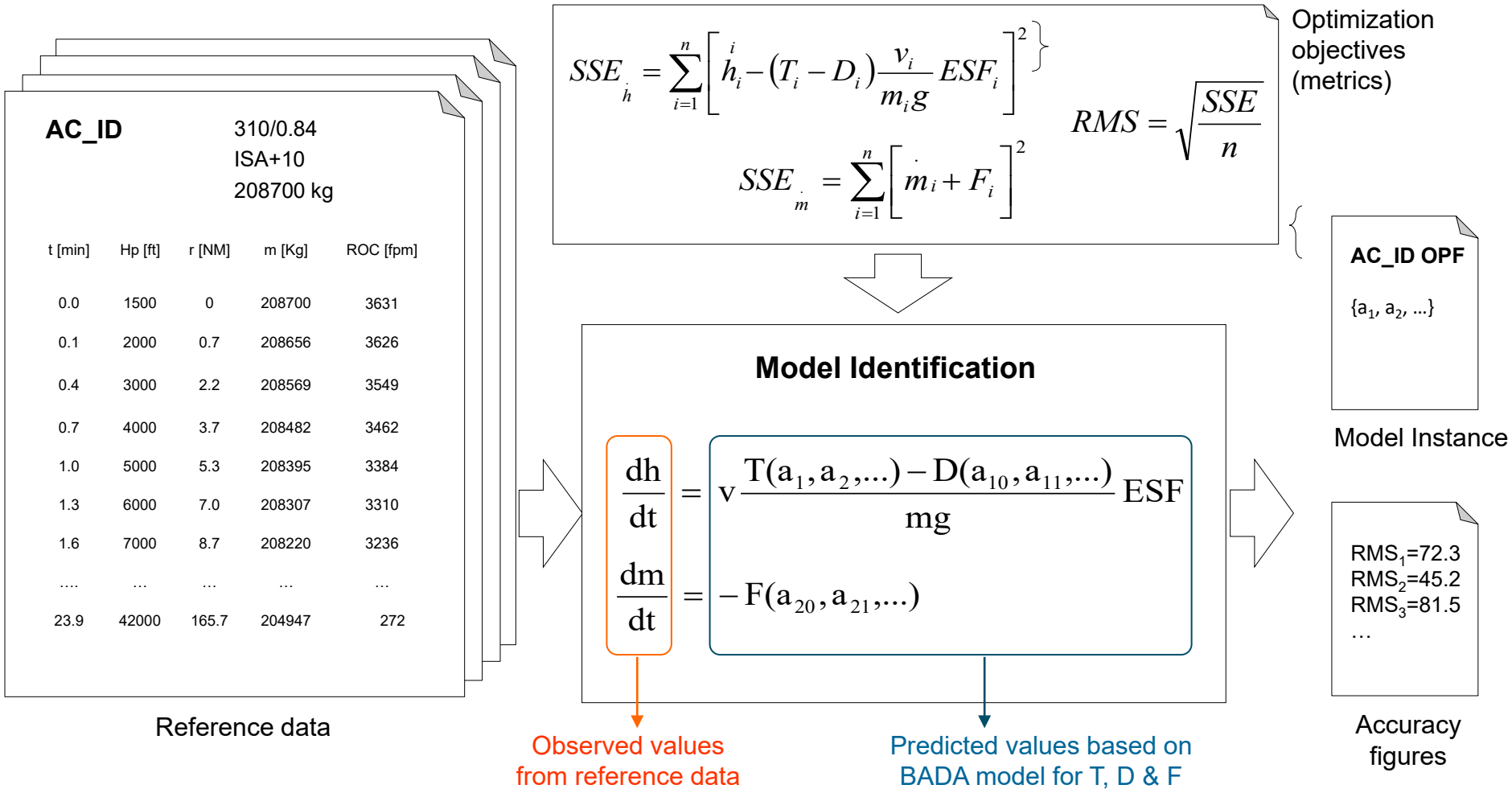
Modelling process: Identification of coefficients



BADA 3 release files

Native models

OPF

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CC                AIRCRAFT PERFORMANCE OPERATIONAL FILE                 /
CC                                                                      /
CC                                                                      /
CC      File_name: A306__.OPF                                           /
CC                                                                      /
CC      Creation_date: Apr 30 2002                                      /
CC                                                                      /
CC      Modification_date: Sep 05 2008                                  /
CC                                                                      /
CC                                                                      /
CC====== Actype ========================================================/
CD   A306__          2 engines    Jet                          H         /
CC  A300B4-622     with PW4158 engines                       wake        /
CC                                                                      /
CC====== Mass (t) ======================================================/
CC     reference      minimum      maximum     max payload  mass grad  /
CD      .14000E+03   .87000E+02   .17170E+03   .39000E+02   .15103E+00 /
CC====== Flight envelope ===============================================/
CC      VMO(KCAS)       MMO         Max.Alt       Hmax       temp grad  /
CD      .33500E+03   .82000E+00   .41000E+05   .32378E+05   -.2716E+02 /
CC====== Aerodynamics ==================================================/
CC Wing Area and Buffet coefficients (SIM)                              /
CCndrst Surf(m2)     Clbo(M=0)       k          CM16                    /
CD 5   .26000E+03   .13150E+01   .84080E+00   .00000E+00                /
CC   Configuration characteristics                                      /
CC n Phase  Name     Vstall(KCAS)    CD0          CD2         unused    /
CD 1 CR   Clean      .15100E+03   .20591E-01   .51977E-01   .00000E+00 /
CD 2 IC   S15F00     .11700E+03   .33057E-01   .45362E-01   .00000E+00 /
CD 3 TO   S15F00     .11700E+03   .33057E-01   .45362E-01   .00000E+00 /
CD 4 AP   S15F15     .10900E+03   .38031E-01   .44932E-01   .00000E+00 /
CD 5 LD   S30F40     .97000E+02   .78935E-01   .44822E-01   .00000E+00 /
CC   Spoiler                                                            /
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APF

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CC                                                                      /
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CC                        mass  lo  hi           lo  hi        hi  lo          (unused)          /
CC     version engines   ma  cas cas mc xxxx xx  cas cas mc  mc cas cas xxxx xx  xxx xxx xxx  opf___ /
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CD  *** **    Default Company                                           /
CD    B4_622           LO  310 310 79          250 310 79  79 290 290          0   0   0  A306__ /
CD    B4_622           AV  310 310 79          250 310 79  79 290 290          0   0   0  A306__ /
CD    B4_622           HI  310 310 79          250 310 79  79 290 290          0   0   0  A306__ /
CC===:=======:=======::==::===:===:==:====:==::===:===:==::=:===:===:====:==::===:===:===::=======:/
CC//////////////////////////////////////////THE END////////////////////////////////////////////////
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PTF

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BADA PERFORMANCE FILE                                          Apr 01 2010

AC/Type: A306__
                                  Source OPF File:             Sep 05 2008
                                  Source APF file:             Mar 05 2009

 Speeds:   CAS(LO/HI)  Mach   Mass Levels [kg]          Temperature:  ISA
 climb    - 250/310     0.79  low      -  104400
 cruise   - 250/310     0.79  nominal  -  140000        Max Alt. [ft]:  41000
 descent  - 250/290     0.79  high     -  171700
=============================================================================================
FL |          CRUISE                |          CLIMB                  |          DESCENT
   |  TAS        fuel                |  TAS       ROCD       fuel      |  TAS  ROCD    fuel
   | [kts]     [kg/min]              | [kts]      [fpm]     [kg/min]   | [kts] [fpm]  [kg/min]
   |          lo   nom   hi          |          lo   nom   hi   nom     |       nom     nom
=============================================================================================
  0|                                 | 157   2454  1925  1556  219.7   | 131   698    84.1
  5|                                 | 158   2437  1907  1536  217.8   | 132   714    83.3
 10|                                 | 159   2420  1889  1517  215.9   | 138   730    82.9
 15|                                 | 166   2530  1974  1588  214.9   | 149   774    82.9
 20|                                 | 167   2512  1955  1568  213.0   | 181   988    28.3
 30|  230   53.3  69.9  88.8         | 190   2940  2289  1852  212.9   | 230   1287   20.2
 40|  233   53.4  70.1  89.0         | 225   3474  2695  2191  214.6   | 233   1306   19.9
 60|  272   60.0  73.3  88.5         | 272   4081  2973  2285  213.7   | 272   1520   19.3
 80|  280   60.3  73.8  89.1         | 280   3932  2846  2168  206.0   | 280   1561   18.7
100|  289   60.5  74.2  89.7         | 357   3897  2879  2256  208.7   | 334   1984   18.0
120|  297   60.9  74.6  90.3         | 367   3687  2706  2101  200.8   | 344   2027   17.4
140|  378   82.2  91.8 102.8        | 378   3472  2527  1941  193.0   | 354   2071   16.8
160|  389   82.4  92.3 103.4        | 389   3250  2344  1776  185.2   | 365   2075   16.1
180|
200|
220|
240|
260|
280|
290|
```

PTD

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BADA PERFORMANCE FILE RESULTS
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Low mass CLIMBS
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 FL[-] T[K] p[Pa] rho[kg/m3] a[m/s] TAS[kt] CAS[kt]    M[-] mass[kg] Thrust[N] Drag[N] Fuel[kgm] ESF[-] ROC[fpm] TDC[N]  PWC[-]
     0 288 101325    1.225     340   136.35   136.35   0.21 104400    297160   85670   215.8    0.98    2454   186284   0.88
     5 287  99508    1.207     340   137.34   136.35   0.21 104400    294268   85680   213.9    0.98    2437   183727   0.88
    10 286  97717    1.190     339   138.34   136.35   0.21 104400    291385   85691   212.0    0.98    2420   181179   0.88
    15 285  95952    1.172     339   144.45   141.35   0.22 104400    288510   82072   211.0    0.97    2530   181833   0.88
    20 284  94213    1.155     338   145.51   141.35   0.22 104400    285643   82082   209.1    0.97    2512   179299   0.88
    30 282  90812    1.121     337   168.52   161.35   0.26 104400    279935   72295   209.0    0.96    2940   182892   0.88
    40 280  87511    1.088     336   202.72   191.35   0.31 104400    274260   67093   210.7    0.95    3474   182476   0.88
    60 276  81200    1.024     333   272.30   250.00   0.42 104400    263011   74643   213.7    0.91    4081   165917   0.88
    80 272  75262    0.963     331   280.34   250.00   0.44 104400    251895   74535   206.0    0.91    3932   156222   0.88
   100 268  69682    0.905     328   356.65   310.00   0.56 104400    240914   95279   208.7    0.86    3897   128277   0.88
   120 264  64441    0.849     326   367.06   310.00   0.58 104400    230066   94890   200.8    0.85    3687   119065   0.88
   140 260  59524    0.796     324   377.86   310.00   0.60 104400    219352   94472   193.0    0.84    3472   109996   0.88
   160 256  54915    0.746     321   389.07   310.00   0.62 104400    208772   94022   185.2    0.84    3250   101073   0.88
   180 252  50600    0.698     319   400.70   310.00   0.65 104400    198326   93539   177.4    0.83    3023    92297   0.88
   200 249  46563    0.653     316   412.77   310.00   0.67 104400    188013   93021   169.6    0.82    2790    83671   0.88
   220 245  42791    0.610     314   425.28   310.00   0.70 104400    177835   92465   161.8    0.81    2551    75195   0.88
   240 241  39271    0.569     311   438.26   310.00   0.73 104400    167790   91869   154.1    0.80    2308    66873   0.88
   260 237  35989    0.530     308   451.70   310.00   0.75 104400    157879   91231   146.3    0.79    2059    58705   0.88
   280 233  32932    0.493     306   465.64   310.00   0.78 104400    148102   90548   138.6    0.77    1807    50694   0.88
   290 231  31485    0.475     304   467.58   306.26   0.79 104400    143263   88873   134.2    1.09    2417    47908   0.88
   310 227  28745    0.442     302   463.54   293.28   0.79 104400    133687   83916   124.9    1.09    2192    43839   0.88
   330 223  26201    0.410     299   459.48   280.58   0.79 104400    124245   79587   115.8    1.09    2214    44658   1.00
   350 219  23842    0.380     297   455.37   268.17   0.79 104400    114936   75881   106.8    1.09    1919    39055   1.00
   370 217  21663    0.348     295   453.12   256.08   0.79 104400    105761   72808    98.1    1.00    1477    32953   1.00
   390 217  19677    0.316     295   453.12   244.46   0.79 104400     96720   70398    89.7    1.00    1180    26322   1.00
   410 217  17874    0.287     295   453.12   233.34   0.79 104400     87813   68640    81.5    1.00     859    19173   1.00
```


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Modelling process: Accuracy figures

- BADA 3: “Model accuracy summary report” (for each release)

TRJ ID	TRJ Type	CAS <FL100	CAS >FL100	M	Aircraft mass	Delta ISA	Comment	RMS [ft/min]	MEAN [ft/min]	STD [ft/min]	MAX [ft/min]	RMS [kg/min]	MEAN [kg/min]	STD [kg/min]	MAX [kg/min]
1	CMB	300	300	0.78	150000	0		59.95	14.89	58.07	136.80	3.58	-0.95	3.45	-8.48
2	CMB	300	300	0.78	210000	0		54.76	16.27	52.29	-125.57	3.11	-1.10	2.91	-7.32
3	CMB	300	300	0.78	255000	0		43.42	1.81	43.38	-134.47	3.88	-1.08	3.72	11.17
4	CMB	280	280	0.74	150000	0		68.10	-1.38	68.09	197.32	3.15	-0.64	3.08	10.71
5	CMB	280	280	0.74	210000	0		61.55	-1.65	61.53	-183.60	2.97	-0.22	2.96	8.39
6	CMB	280	280	0.74	255000	0		48.43	-10.23	47.33	-164.02	2.83	-0.10	2.83	7.21
7	CMB	320	320	0.82	150000	0		76.95	-31.10	70.38	-195.33	4.91	-2.09	4.45	-13.80
8	CMB	320	320	0.82	210000	0		49.82	5.78	49.48	-120.28	4.54	-2.36	3.87	-10.07
9	CMB	320	320	0.82	255000	0		42.75	3.07	42.64	-108.29	4.86	-2.90	3.90	-10.16
10	CMB	300	300	0.78	150000	10		60.20	3.11	60.12	-132.60	4.25	3.18	2.82	9.12
11	CMB	300	300	0.78	210000	10		52.90	7.52	52.36	-128.36	4.51	3.21	3.16	13.49
12	CMB	300	300	0.78	255000	10		43.78	-6.23	43.34	-136.78	4.36	3.13	3.04	9.70
13	CMB	300	300	0.78	210000	20		59.96	3.96	59.83	-123.04	5.58	4.30	3.57	12.54
14	DES	300	300	0.78	180000	0		106.94	26.85	103.51	-259.71	3.54	0.24	3.53	-9.21
15	DES	280	280	0.74	180000	0		97.75	17.70	96.13	-228.22	3.97	-0.48	3.94	-7.29
16	DES	320	320	0.82	180000	0		153.68	-25.73	151.51	-328.62	4.60	0.24	4.59	9.98
17	CRZ	310	310	0.80	210000	0						3.06	0.09	3.06	7.59

- BADA 4: Accuracy Tables Files (ATF) are part of the release files

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BADA APM families

BADA 3	• Today's standard fixed-wing APM • Models aircraft behavior over nominal part of flight envelope • Meets today's requirements for aircraft performance modelling and simulation	**100% of ECAC IFR operations** **264 (95%) models +** **1627 (5%) synonyms**
BADA 4	• New fixed-wing APM developed to meet requirements of future ATM systems • Provides increased levels of precision in aircraft performances parameters over the entire flight envelope • Enables modelling and simulation of advanced systems and future concepts	**83% of ECAC IFR operations** **106 models**
BADA H	Helicopter APM	**96% of ECAC IFR operations** **26 models**

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BADA Product components

BADA APM

- Releases files and doc's
- Modelling reference data and documents

Support Tools

- Web User Interface (licencing platform, data repository, set of performance calculation tools, support request tool)
- pyBADA

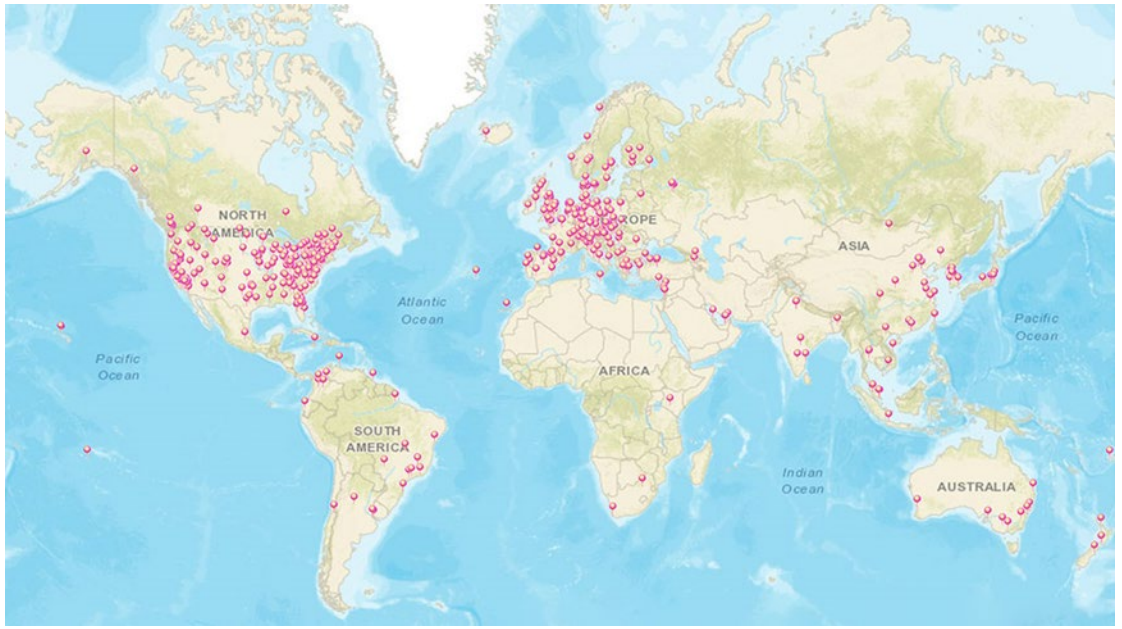
Support Services

- Maintenance and support
- Technical support
- Training

BADA is not a software product!

BADA Users

- BADA is free of charge
- Use is governed by a licence agreement
  - Web licencing per model family and intended use



EUROCONTROL

Permitted use of BADA

- Almost 30 years of efforts in building partnership with aircraft manufacturers, resulted in:
  - Active partnership and data agreements in place with Airbus, ATR, Boeing, Embraer
  - Data agreement with Dassault, BAE Systems, Eclipse, Diamond
  - The process is very long and cumbersome, requires determination of individuals, persuasion …. to gain confidence of aircraft manufacturers

Permitted use of BADA

- ATM R&D modelling and simulation
- Non-safety-critical ATC operational applications
- Environmental assessments
- Education and training
- New use cases continuously discussed with manufacturers in order to expand the scope of BADA permitted use
  - Pilot decision support tools
  - Airline post flight analysis and modelling
  - Travel Impact Models
  - Env Noise

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Forbidden use of BADA

- All safety-critical ATM applications and systems
- Any comparisons of any kind between aircraft types (from the same or different aircraft manufacturers) where the intent of such a comparison is to identify a direct relationship between aircraft performances. However, general (system-wide) comparisons of aircraft performance of different aircraft types for research purposes to assess ATM system performances may be allowed
- Aircraft flight planning and flight dispatch purposes
- Private persons

EUROCONTROL

Application Domain	Intended Use	BADA 3 No. Licences*	BADA 4 No. Licences*	Example Users
ATM R&D	Simulation and modelling tools for wide range of R&D	427 [50%]	90 [63%]	Major R&D and education institutions ENAC, NLR, DLR, DFS, ONERA, MITRE, MIT, NASA, FAA, ENRI, JAXA
Operational systems	ATC operational systems Air traffic flow and capacity management	178 [21%]	0	Major European and worldwide ANSPs (FAA, Nav Canada, Australia, India, China, Singapore, South America, South Africa, New Zealand)
Environment	Emissions	154 [18%]	30 [21%]	IMPACT, AEM, FAA AEDT**
	Contrails			DLR, ONERA, Imperial College London, MIT
Education and training	ATCOs, aviation related studies	74 [9%]	20 [14%]	ENAC, SKGUIDE, Bulatsa, ENAIRE, TU Delft, TU Berlin
ATM Industry Commercial Tools	R&D	28 [3%]	2 [2%]	AirTop, ARC CAST, AGENTFLY TECHNOLOGIES, Jeppesen, MITRE, Micronav, UFA, TRANSOFT SOLUTIONS, ISA SOFTWARE; SIM SOFT, CS GROUP, METRON, VIANAIR INC
	OPS tools and systems			THALES, Indra, Harris Orthogon, Leonardo, ATECH, Tern Systems

* Number of licences @April 2024 approved over the last 5 years

** 779 licences issued for use of BADA in FAA AEDT

EUROCONTROL

Partners and ‘customers’ …

BADA User Group meetings

BOEING
Washington DC

NATS Prestwick

NAV CANADA CENTRE
Cornwall, Canada

EUROCONTROL

Open aircraft performance data

- What are the needs for open aircraft performance data:
  - Use cases that are not covered by BADA?
  - What capabilities in terms of performance parameters, envelope coverage, precision, …?

Web site and Contacts

- BADA home pages: https://www.eurocontrol.int/model/bada
  https://ext.eurocontrol.int/bada/
- BADA support team: eih.bada@eurocontrol.int
- Project manager: angela.nuic@eurocontrol.int

EUROCONTROL

SUPPORTING
EUROPEAN
AVIATION

Thank you!

angela.nuic@eurocontrol.int

www.eurocontrol.int

CONSORTIUM COORDINATOR sesar DEPLOYMENT MANAGER

FOUNDING MEMBER sesar JOINT UNDERTAKING

NETWORK MANAGER