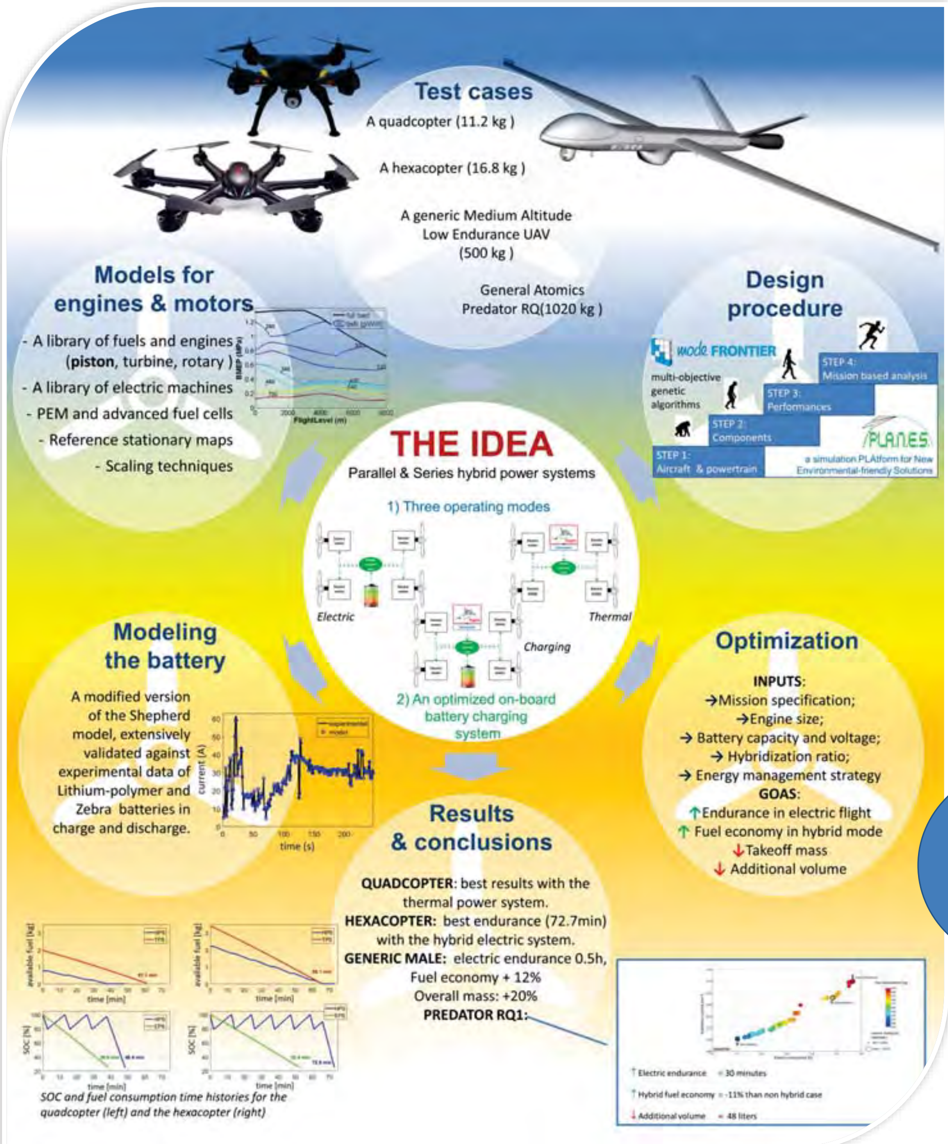
# Many objective optimization of advanced power systems for aircraft

Teresa Donateo, Claudia L. De Pascalis, Antonio Ficarella
Dipartimento di Ingegneria dell'Innovazione, Università del Salento, ITALY




## Which is the best algorithm?

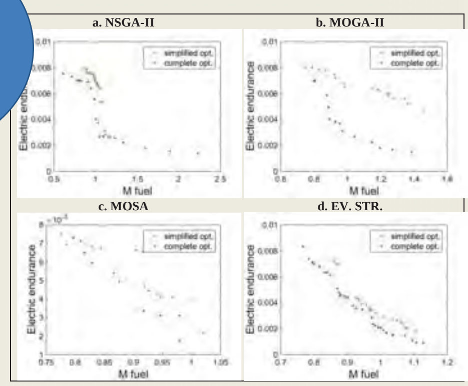
### Performance metrics

- Hypervolume **(hv)**
- Generational Distance **(GD)**
- Inverted Generational Distance **(IGD)**
- Average distance between solutions **(Davg)**
- Distance variance between solutions **(Var)**
- Number of non-dominated solutions **(NNS)**
- Number of feasible solutions **(NFS)**
- Maximum or Minimum sum of the objective values **(MaxSum/MinSum)**
- Sum of the maximum objective values **(SumMax)**
- Sum of the ranges of the objective values **(Range)**
- Computational time **(time)**
- Percentage of a Pareto front dominated by the other one **(C_AB)**

## HYBRID ELECTRIC UAV (Test case 1) SYNERGY BETWEEN POWER SYSTEM AND MISSION

**BI-OBJECTIVE problem**

### Objective functions: electric endurance & fuel consumption




### Four goals: electric endurance, fuel consumption, additional volume & take-off field length

**Many-Objective problem**

| C(A,B) | B | | | | |
|---|---|---|---|---|---|
| A | MOGAII | NSGAII | MOSA | Ev. Str. | REAL |
| MOGAII | | 38% | 7% | 6% | 28% |
| NSGAII | 4% | | 5% | 15% | 18% |
| MOSA | 27% | 32% | | 35.6% | 50.1% |
| Ev. Str. | 24.8% | 35.4% | 8.1% | | 35.6% |

| Parameter | MOGAII | NSGAII | MOSA | EV. STR. |
|---|---|---|---|---|
| n_NNS | 3946 | 4204 | 1668 | 4871 ☺ |
| Davg | 0.0411 | 0.0413 | 0.0586 | 0.0405 ☺ |
| Var | 0.0051 | 0.0013 | 0.0022 | 7.6648e-04 ☺ |
| GD | 0.0270 | 0.0444 | 0.0288 | 0.0243 ☺ |
| IGD | 0 ☺ | 1.5701e-16 | 0 ☺ | 8.6736e-19 |
| hv | ≈0.4230 | ≈0.4640 ☺ | ≈0.4190 | ≈0.4050 |

### Conclusions for test case 1

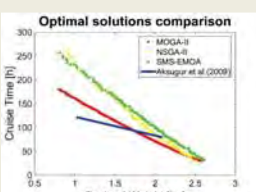
- MOGAII is the best method in the bi-objective optimization problem
- NSGAII that turns out to be the best method in the many-objective optimization problem
- Evolution Strategy gets the best definition and distribution
- MOSA is the worst method for this application

**Performance degradation in many-objective optimization is always observed**

## ELECTRIC VTOL (Test case 2) SYNERGY BETWEEN AIRCRAFT ARCHITECTURE AND ELECTRIC POWER SYSTEM

### Objective functions: cruise time and payload

**BI-OBJECTIVE problem**




| | MOGA-II | NSGA-II | SMS-EMOA |
|---|---|---|---|
| NNS | 318 | 90 | 149 |
| NFS | 6˙916 | 10˙810 | 11˙959 |
| Var | 0.0729 | 0.0010 | 3.0484e-04 |
| Davg | 0.2374 | 0.0279 | 0.0203 |
| HV | 0.4228 | 0.6426 | 0.6859 |

| C(A,B) | B | | |
|---|---|---|---|
| A | MOGA-II | NSGA-II | SMS-EMOA |
| MOGA-II | - | ~93% | 100% |
| NSGA-II | ~6% | - | ~87% |
| SMS-EMOA | 0% | ~9% | - |

### Four goals: cruise time, payload, range, takeoff area

**Many-Objective problem**

| | MOGA-II | NSGA-II | SMS-EMOA |
|---|---|---|---|
| NNS | 477 | 352 | 150 |
| NFS | 4˙304 | 10˙997 | 14˙324 |
| Var | 0.2461 | 0.1929 | 0.3355 |
| Davg | 0.2672 | 0.4531 | 0.8178 |
| HV | 0.6419 | 0.9681 | 0.9574 |

| C(A,B) | B | | |
|---|---|---|---|
| A | MOGA-II | NSGA-II | SMS-EMOA |
| MOGA-II | - | 100% | 100% |
| NSGA-II | 0% | - | 0% |
| SMS-EMOA | 0% | 100% | - |

### Conclusions (test case 2)

- MOGA-II is the worst method in both problems
- SMS-EMOA is the best method in the bi-objective problem, followed by NSGA-II
- NSGA-II is the best method in the four-objective problem
- In the many-objective optimization field, SMS-EMOA is only slightly worse than NSGA-II and vice versa in the bi-objective problem
- Exploiting the synergy between structures and power systems, a large improvement in all goals can be obtained.

*NOTE: This test case considers a higher number of design variables and constraints than test case 1*