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8th EMship cycle: September 2017 – February 2019

Master Thesis

Blade Element Momentum Theory numerical model of a tidal turbine in a realistic time-dependent environment

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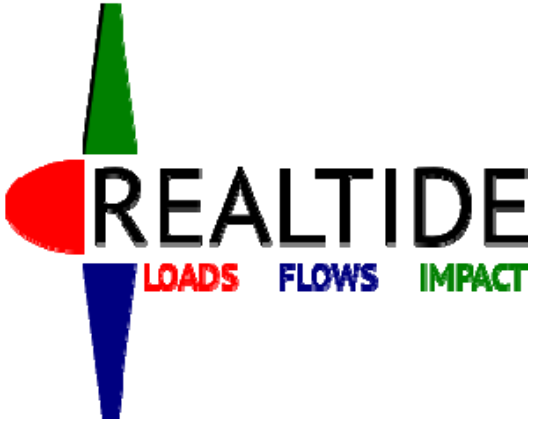
Hamburg, February 2019

About the Project

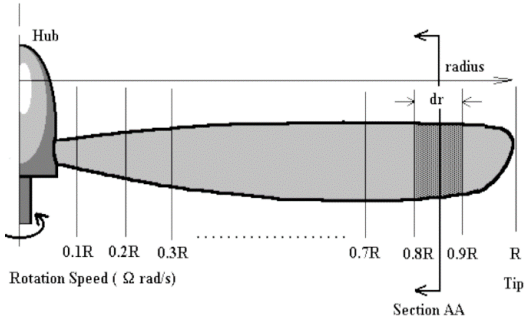
- Internship at Bureau Veritas Marine & Offshore, Nantes
- Project undertaken as part of RealTide project (WP3, Task 3.1)
- Objective of WP3, Task 3.1 : to develop a tide-to-wire model using Blade Element Momentum Theory (BEMT)
- Work undertaken in this master thesis: Develop a Python tool using BEMT that can predict the forces generated by a tidal turbine in realistic flow conditions
- Validation with experimental and CFD results
- Capability for future integration with electrical module and CFD



BEMT: An overview

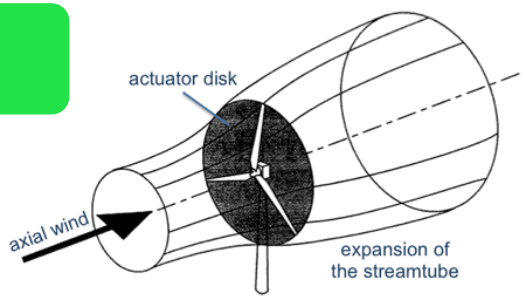
Blade Element Theory

- Blade → individual blade elements (BE)
- Forces on BE: lift and drag experienced during the flow
- Total Force = Σ forces in BEs



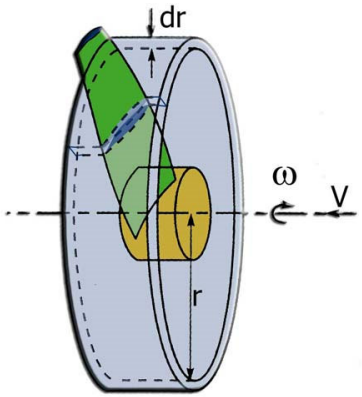
Actuator Disk Momentum Theory

- Based on Newton's Second Law of Motion
- Change in velocity of fluid represented in terms of induction factors: Axial Induction Factor (a) and Tangential Induction Factor (b)

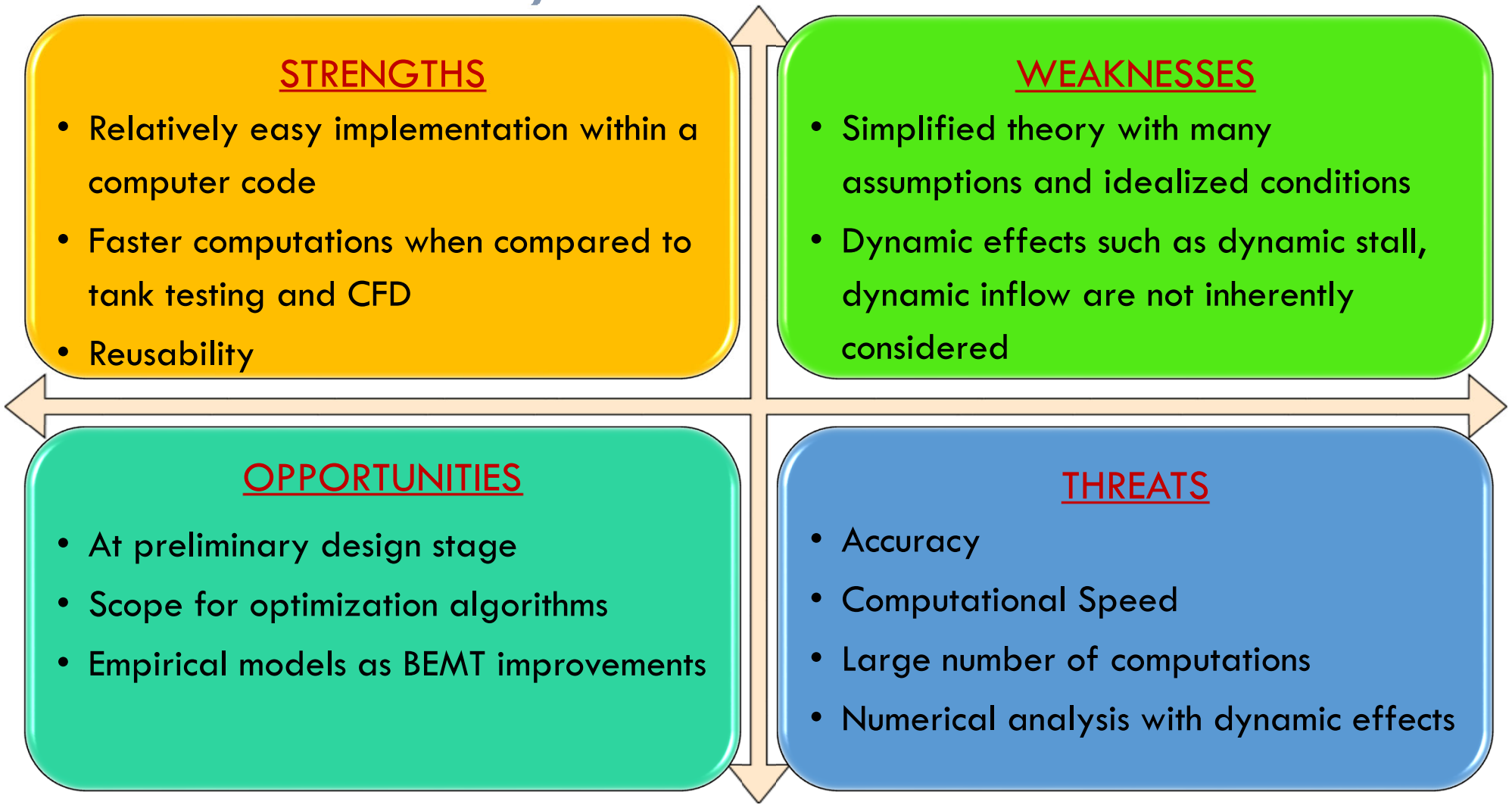


Blade Element Momentum Theory

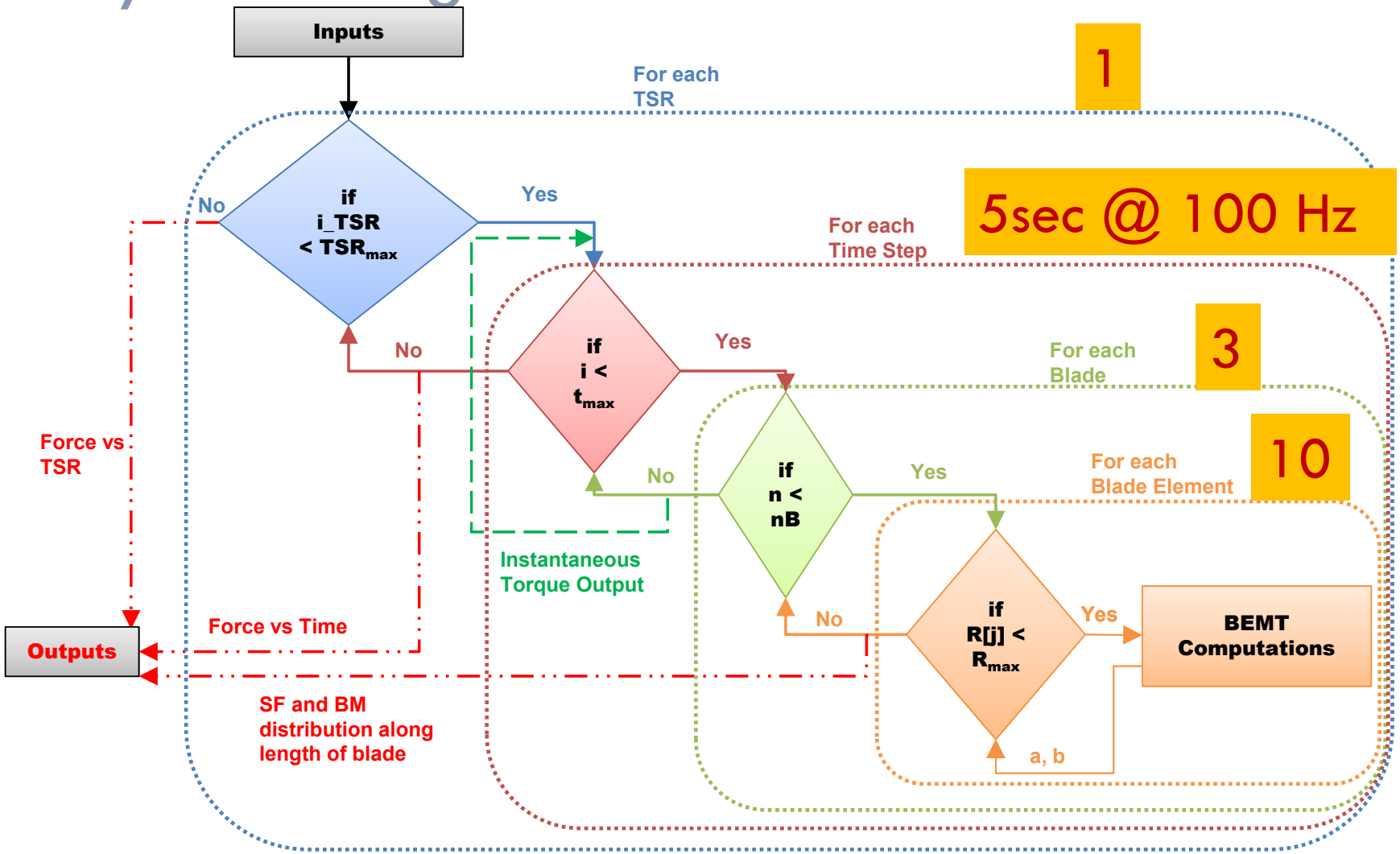
- Combines Blade Element theory and Actuator Disk Momentum theory
- Each blade element considered as an actuator disk; independent of other blade elements
- a & b expressed in terms of the lift and drag coefficients of the BE



BEMT: SWOT Analysis



Python Program Architecture



15000 !!

- For single TSR input, TSR loop is omitted
- For steady flow, time loop is omitted
- Feedback loop provides link between BEMT module and electrical module → instantaneous torque used to calculate instantaneous RPM

Output Parameters

Feedback Loop for Electrical Module

Blade Elements Loop

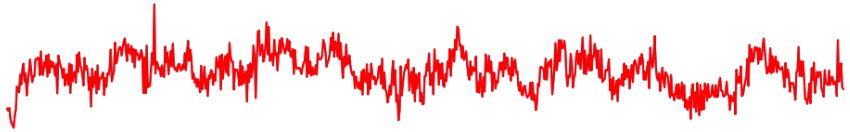
Blades Loop

Time Loop

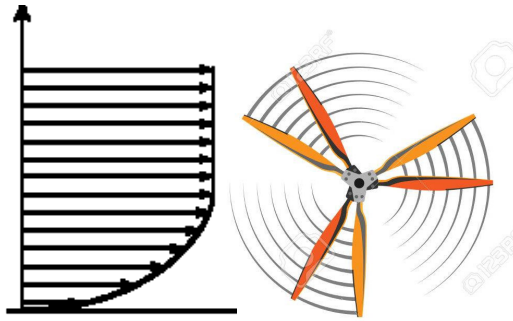
TSR Loop

Inflow Conditions

- In the simplest scenario, the inflow is a constant steady stream velocity
- Variation with time (dynamic inflow):
  - The velocity in a time-dependent environment is not constant
  - Can be due to waves, tidal flow, or ocean currents
  - Turbulence in the flow



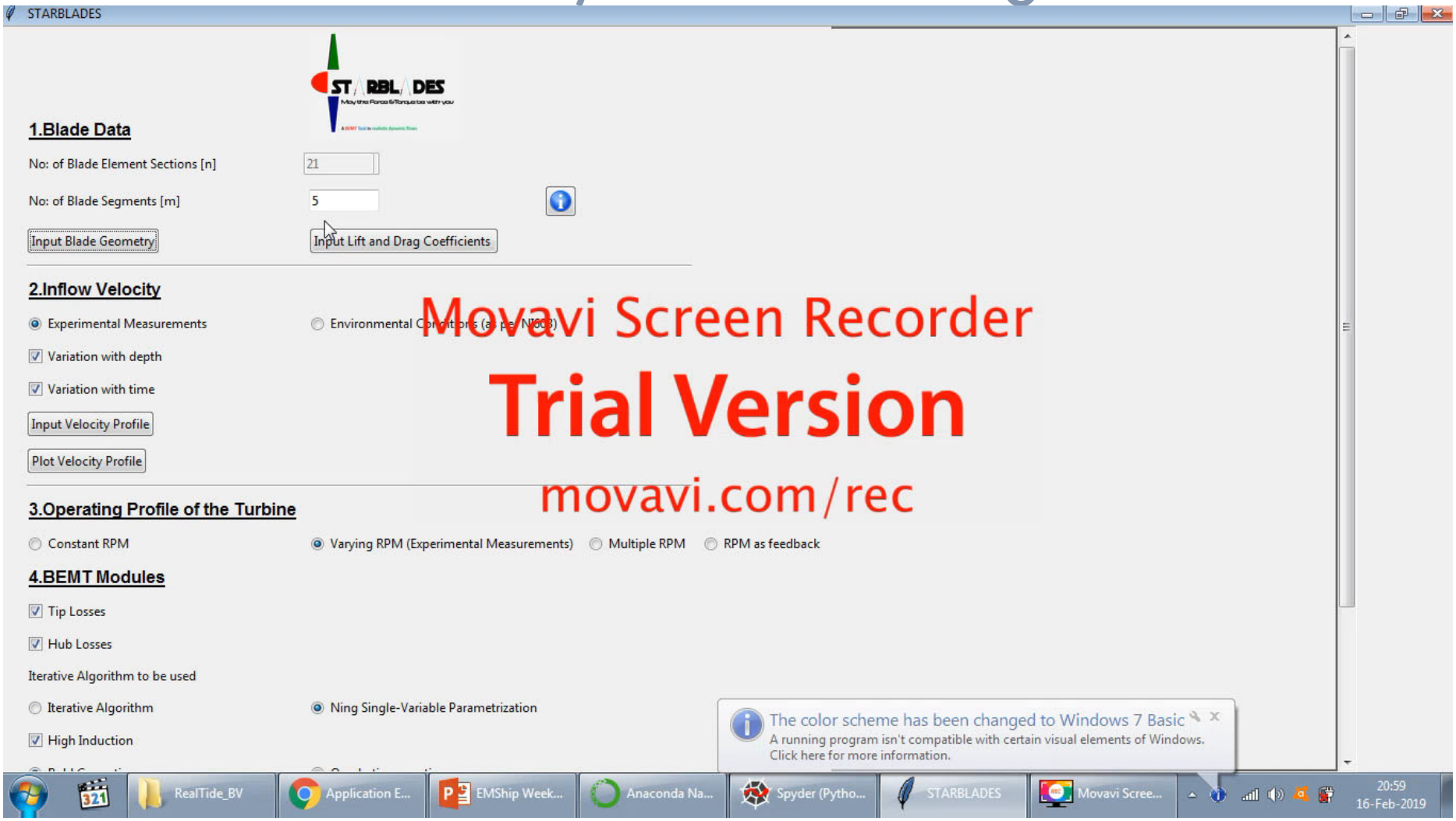
- Variation with depth:
  - Each blade element would experience a different inflow velocity
  - In a time dependent environment, the local inflow velocity would also depend on the instantaneous location of the blade element (due to rotation)



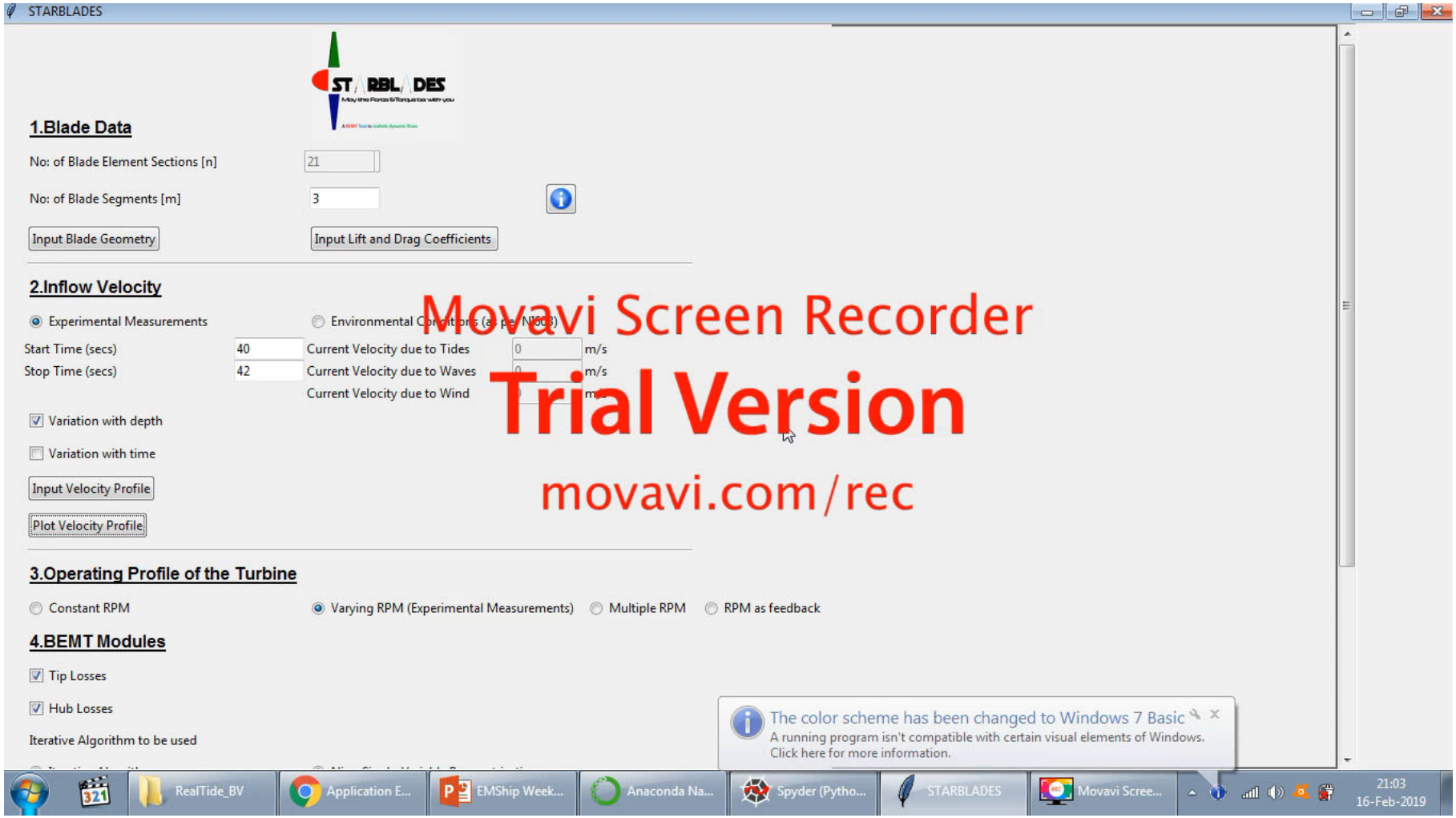
- Computational complexity:
  - Instantaneous position of the blade element to be determined based on the rotational speed
  - Instantaneous velocity depends on instantaneous position and the time

User Interface – 1) Blade Geometry

User Interface – 2) Lift and Drag Coefficients

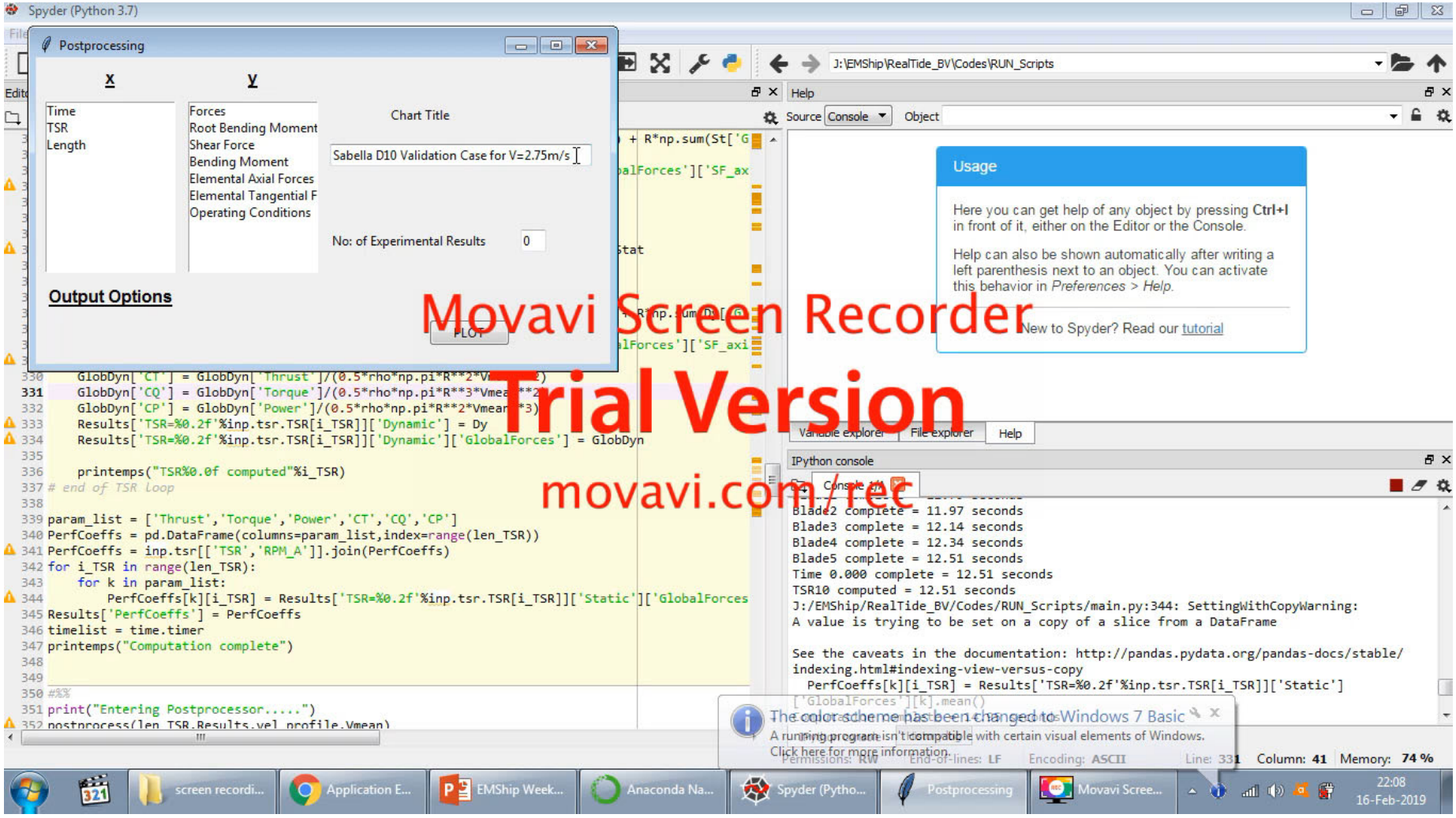


User Interface – 3) Velocity Input

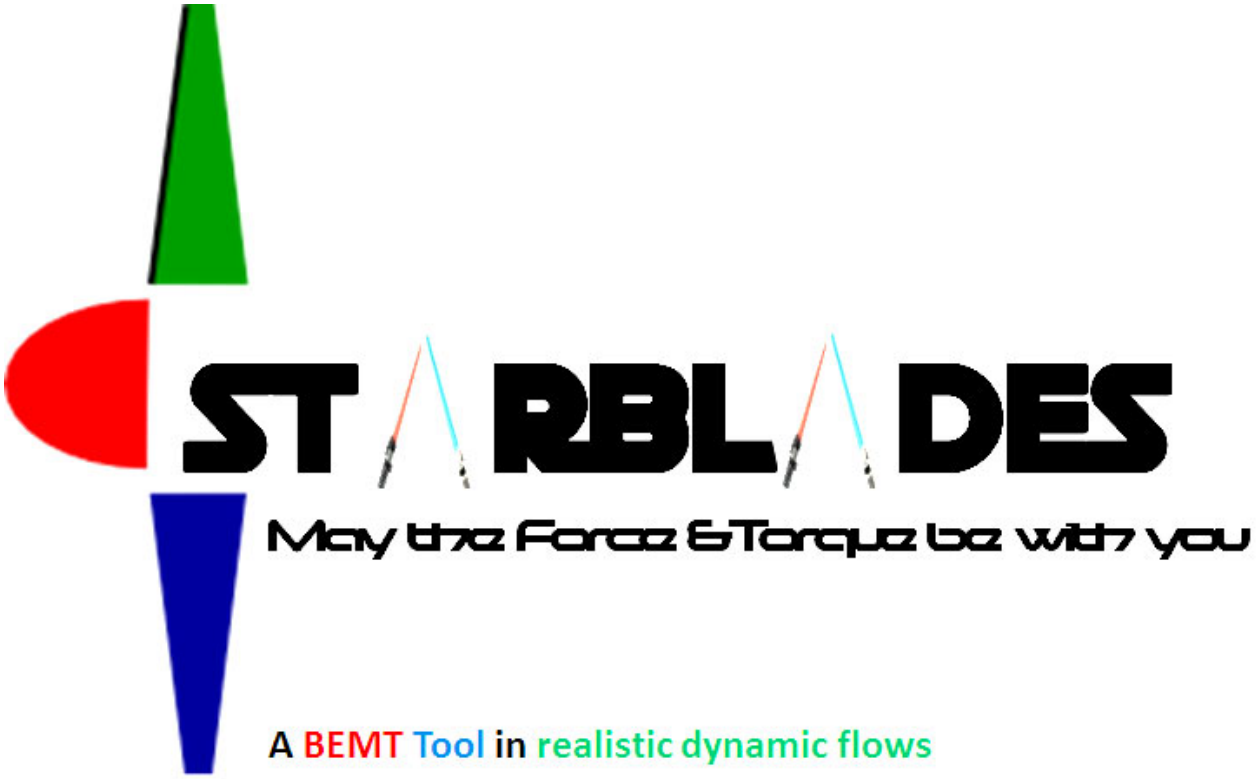


User Interface – 4) BEMT Modules

User Interface – 5) Postprocessing



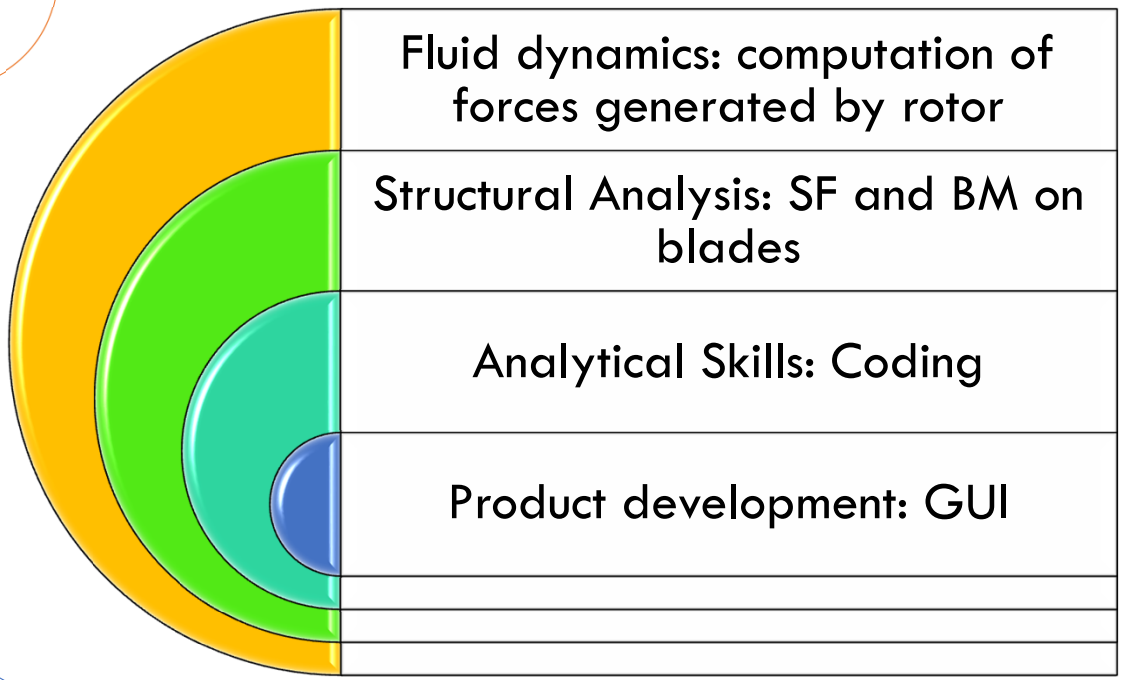
Logo and Motto



Summary

- Python code developed for computation of forces on a tidal turbine
- Realistic Scenario: Time variation and depth-wise variation in velocity profile considered
- BEMT improvements added as modules
- Preliminary User interface developed

Knowledge Application



Future Work

- Integration with electrical module
- Improve computational speed
- Validation with sea test results
- Additional BEMT improvements
- Convergence study
- User interface improvement
- Design optimization tools

✓ Tool will be used and further developed by BV for Structural Analysis of turbine blades

✓ Tool will be used as part of RealTide project and be coupled with electrical module, turbulence simulator model and CFD

THANK YOU...

STARBLADES

May the Force &Torque be with you

A BEMT Tool in realistic dynamic flows