How do I think Research

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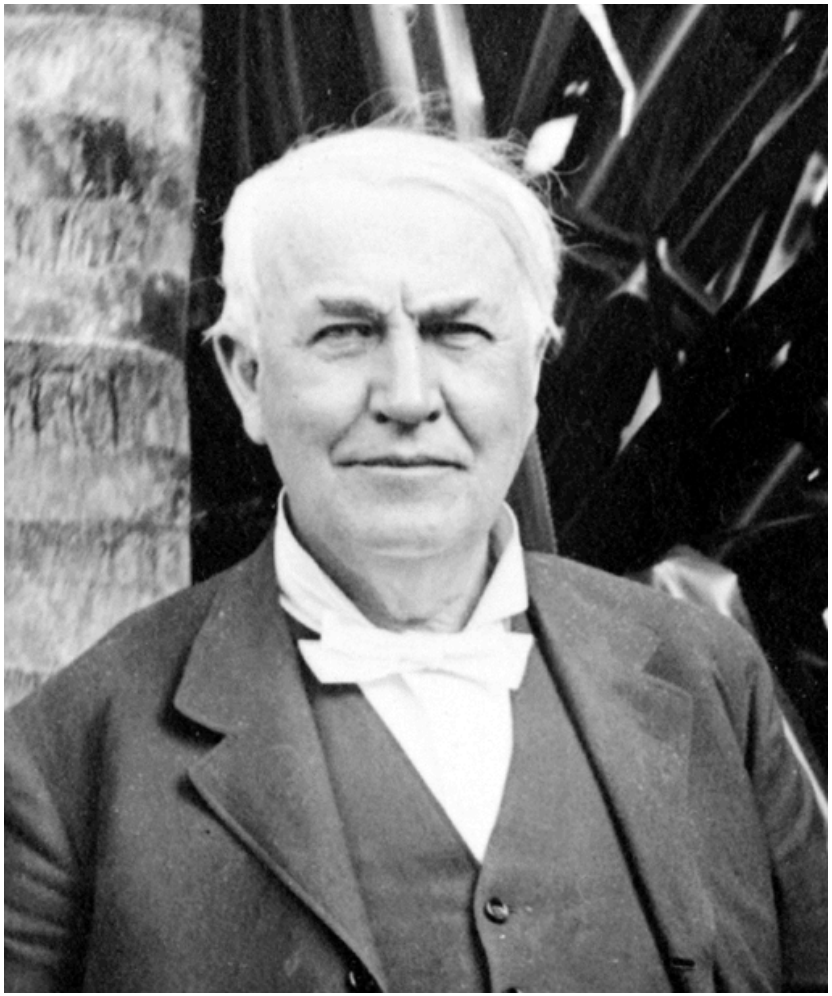
Audience

This talk is not for absolute geniuses … they don’t need any advice

… it is for the 99.99% of the rest (like me) who venture into research

What's Genius

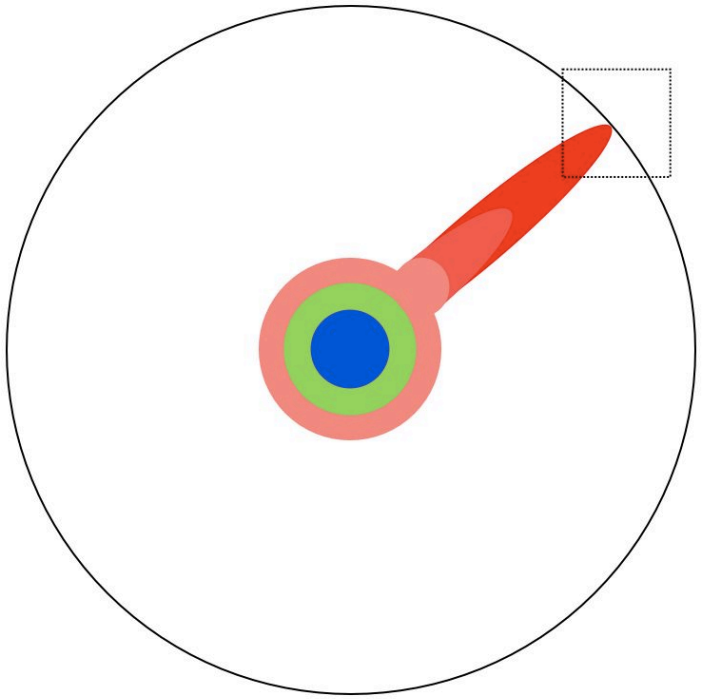
Genius is 1% inspiration,
99% perspiration



Portrait of Thomas Edison

What's a PhD

- http://matt.might.net/articles/phd-school-in-pictures/



Borrowed from: Matthew Might (Prof. at Univ. of Utah)

My Background & Research Interests

- Background
  - 7 years at GE Global Research Center
  - PhD & MS: Penn State in Aero
  - BS: IIT Bombay in Aero

- Research interests:
  - Modeling of aerodynamically generated sound
    - Turbomachines: fan / compressors
    - Wind turbines
    - Sound propagation
  - Aerodynamics of wind turbines & farms
    - Single turbine – wake evolution, etc.
    - Turbine-turbine & weather-turbine interactions

Difference between Industrial & Academic Research

Industry	Academia
• Problem identified for you	• You find the problem
• Imprecise environment → don't know everything for a *complex system*	• Pristine/ideal environment → know everything precisely for a *simple system*
• Impact → real products that affect daily lives	• Impact can be elusive … distant … but revolutionary

It All Begins with an Idea

- Ideas don't just present themselves … you have to generate them

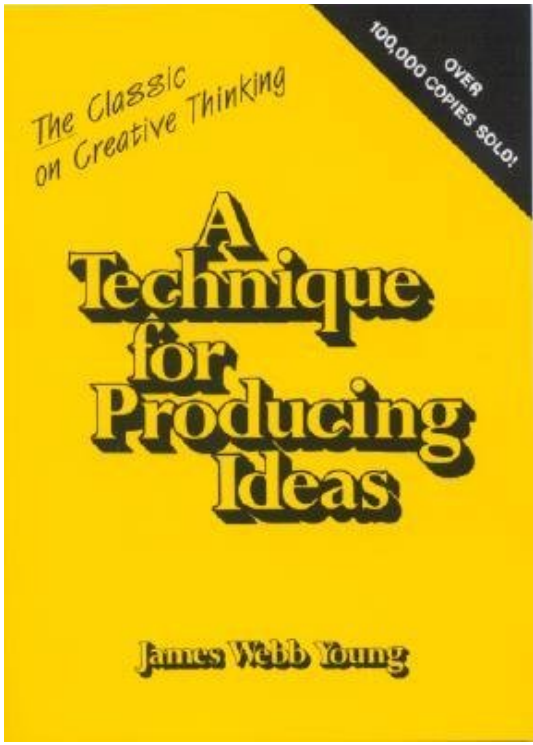
- Not your adviser … you!

- How does one generate ideas?

A recipe … simple to understand … difficult to implement … sure to succeed

Five Steps to Idea Generation

1. Gathering of raw material
2. Digestion of gathered material
3. Incubation stage
4. Birth of the idea
5. Shaping & development of the idea



Step #1: Gathering Raw Material

1. Specific
   - Literature review; data; talking to people who have worked in the area
   - Cover all bases … can be exhausting but very rewarding in the end
   - Spend a lot of time here … much more than you think is satisfactory

2. General
   - Read enough about peripheral topics … *ideas are a new combination of old things*!

Organize your data

Step #2: Digestion of Gathered Mtl.

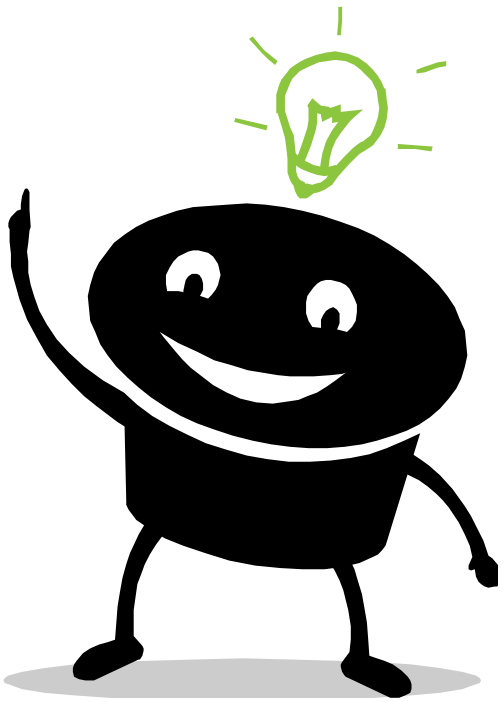
- Think like a cow! "Masticate" the material
- Rephrase each data/paper in your own words … specific contributions? Assumptions? To do items? Gaps?
- Divide gathered material into subgroups … identify themes / trends
- A lot of thinking goes here. Think hard!
  - Elon Musk: "If your head doesn't hurt, you are not thinking hard enough"
- As you analyze data you will find more references …
  - Invariably go back & forth between steps 1 & 2
  - At some point you will close the loop (on most items) ... judiciously choose when to stop

Step #3: Incubation Stage

- Conscious to sub-conscious brain
- I am sure you have all experienced solving a seemingly tough problem easily after a break/nap/some other activity that took your attention to something else
  - Break old links and form new links that lead to problem solving
- Don't use this time to procrastinate … you need to have done steps #1 & #2 thoroughly to gain anything out of this
- Several half-baked ideas will come at this stage … evaluate them objectively and be ready to trash a bunch

Step #4: The Eureka Moment!

The idea will just pop up in your mind in most unusual of places … at most unusual times!



Step #5: Shape & Develop your Idea

- Take your newborn idea to the world of reality
- Do the necessary work to show your idea has merit
  - Proof-of-concept results
  - Validation
  - Application

- More of this required in industry where the output is palpable products
- In academia you still need this to publish papers, get grants etc.

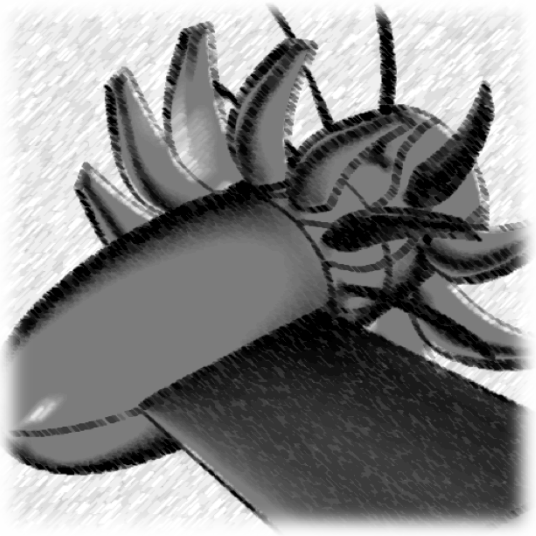
Specific Examples

1. Open Rotor noise modeling
2. A novel dual-rotor turbine concept
3. Influence of nocturnal low-level jets on wind turbine aero & noise
4. Role of wake turbulence in noise

EXAMPLE #1

Open Rotor

- Counter-rotating propellers or fans

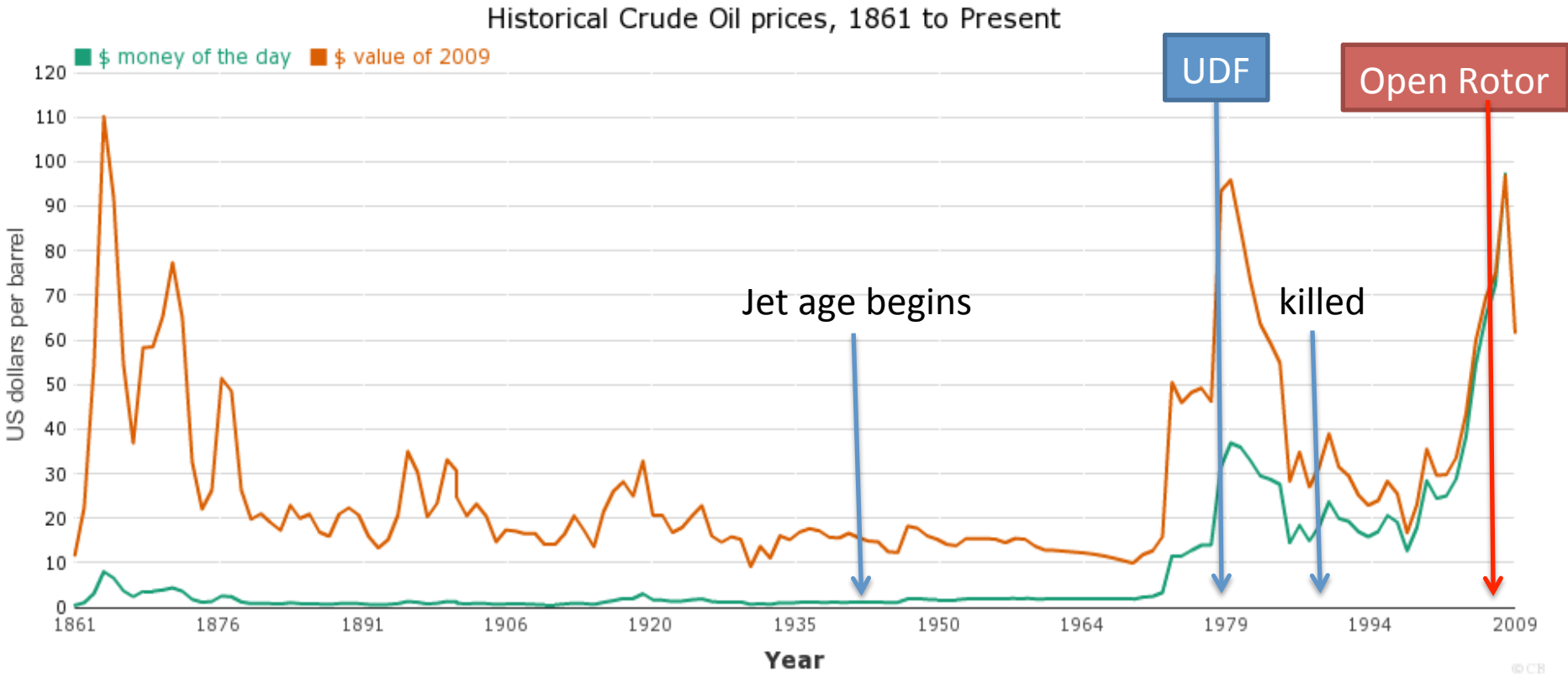


- Concept proposed & flight tested in 1980s ... “un-ducted fan” (UDF)

- Configurations:
  - Pusher or puller configuration
  - Wing or fuselage mounted

Fuselage-mounted, pusher configuration

UDF / Open Rotor – History / Future



Borrowed from: http://cdn3.chartsbin.com

Old ideas recycled! shortsightedness … ?

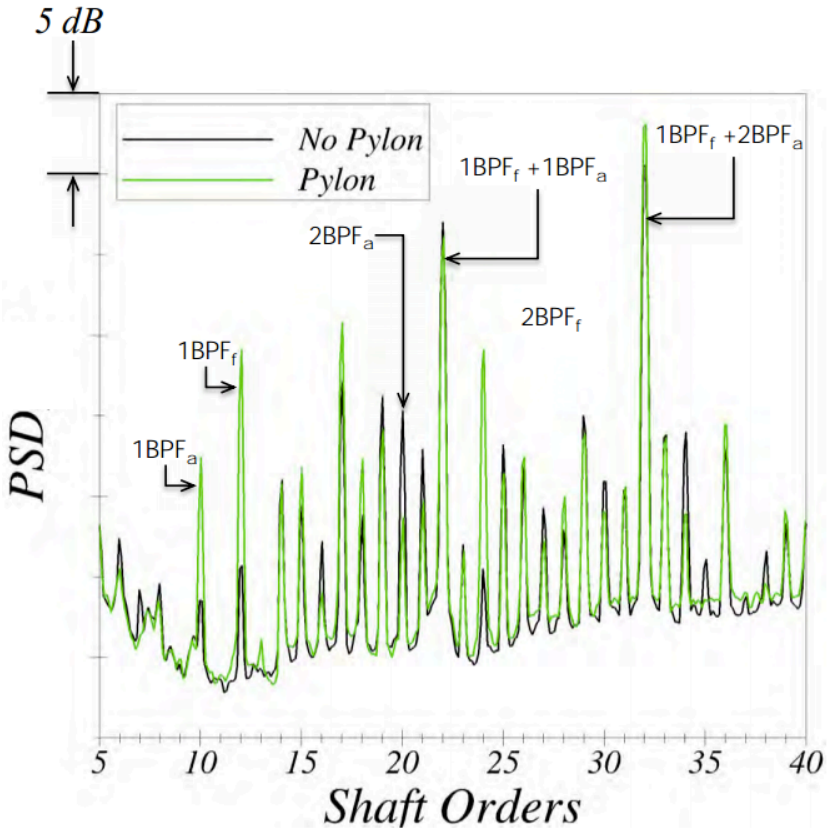
Step #1: Gathering Raw Material

Material (specific)

- 1980s test data:
  - Many configurations
  - aero & acoustic data
- Publications
- Numerical / analytical models developed earlier

Material (general)

- Noise modeling techniques
  - For ducted engines
- Turbomachinery aerodynamics



Acoustic data sample from 1980s tests

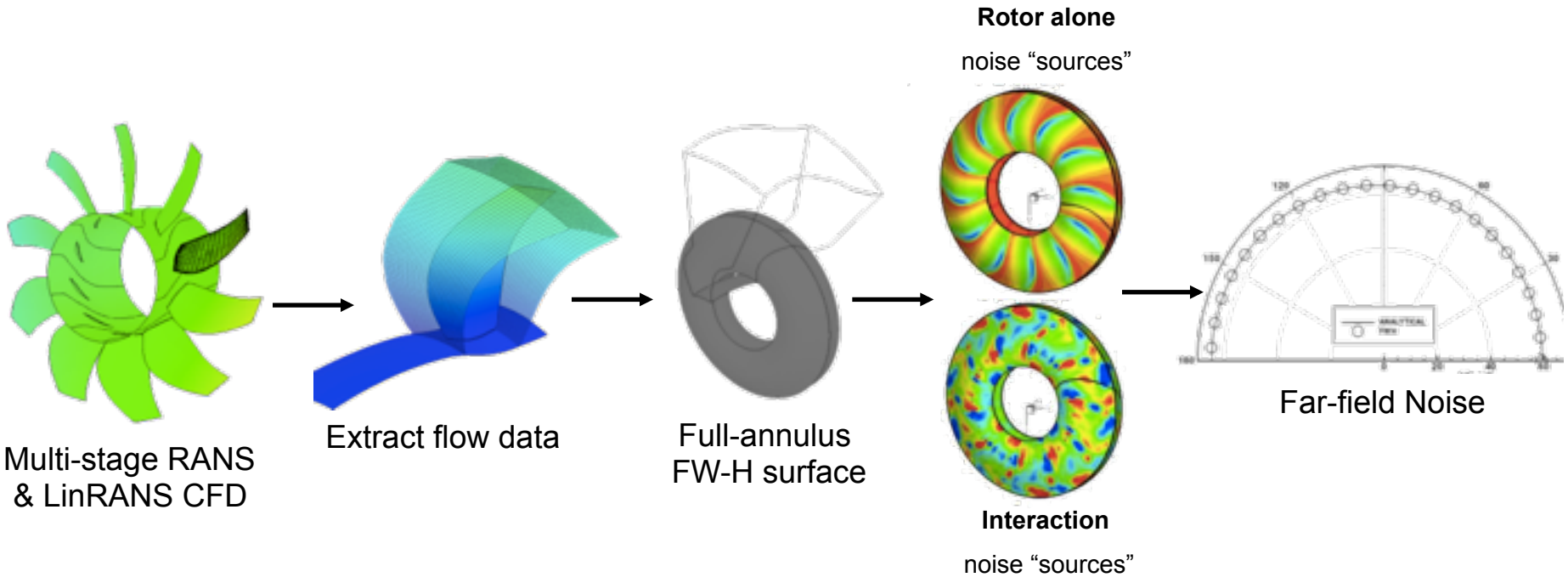
Probably still didn't spend enough time on this!

Step #2: Digestion of Gathered Mtl.

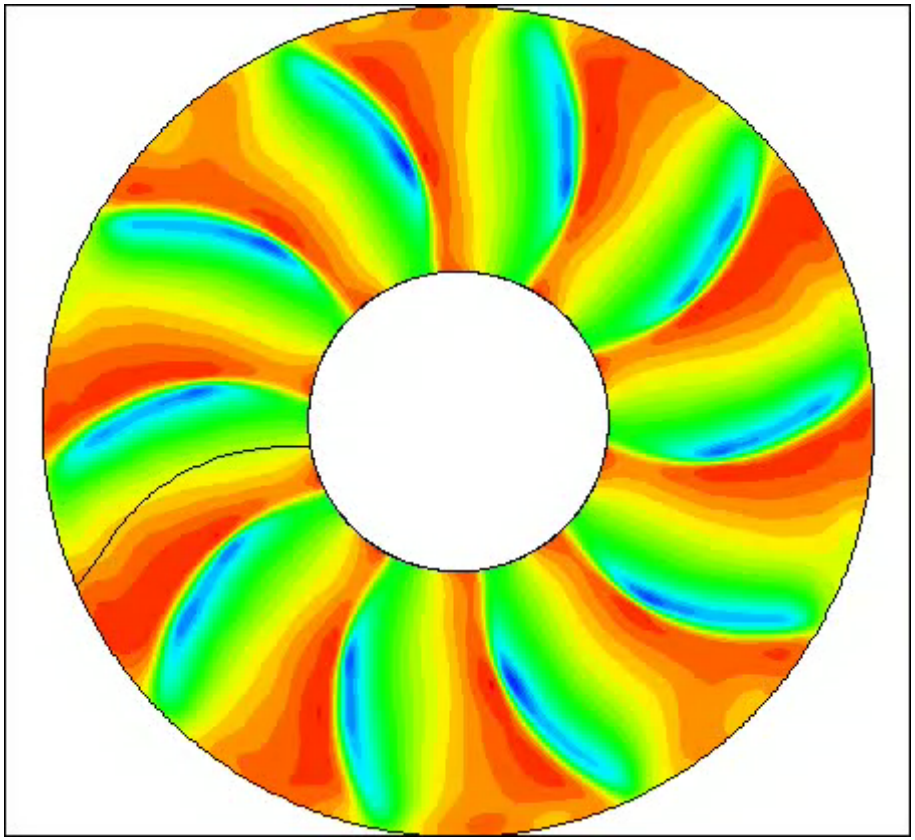
- What is important & when
  - Community noise; tonal; during takeoff
- What produces noise
  - Chopping of upstream bladerow wake/vortex by downstream rotor
- Mechanism linear / non-linear?
- Near-field / far-field?
- What approximations can be made?
- Previous methods codes → ignored blade geometry … semi-empirical → can't guide blade design

Steps #3 & #4: The Idea

- Use linearized, frequency domain CFD methodology for homogeneous inflow
  - Build upon existing capability for ducted engines

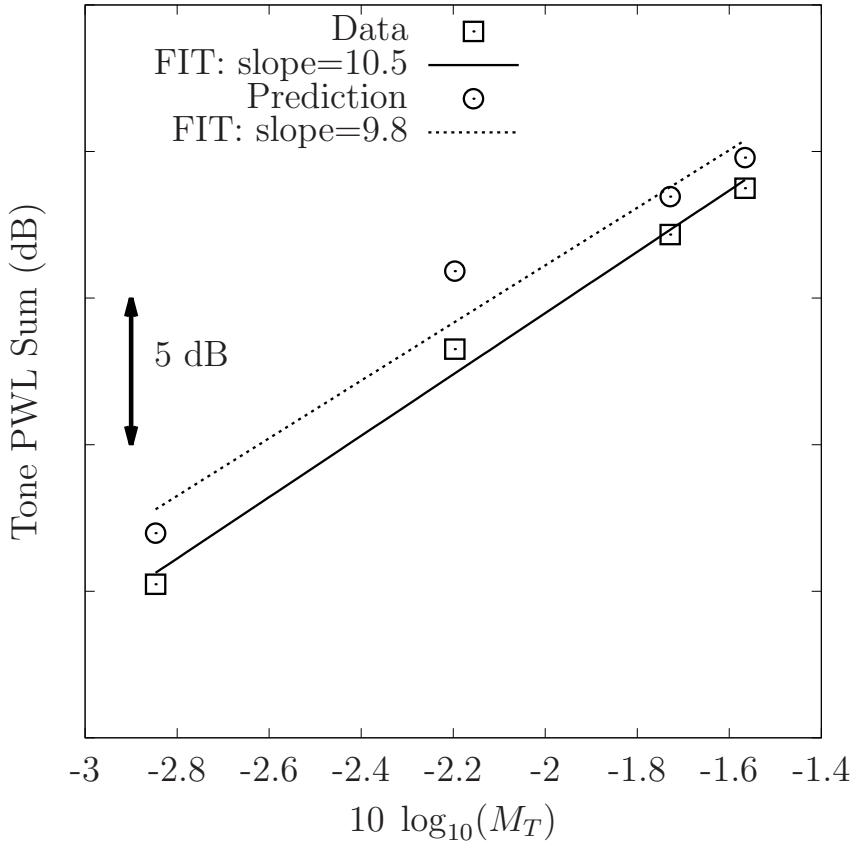


Sample Results



Total pressure field

Aft bladerow - view looking downstream



Prediction compared to data

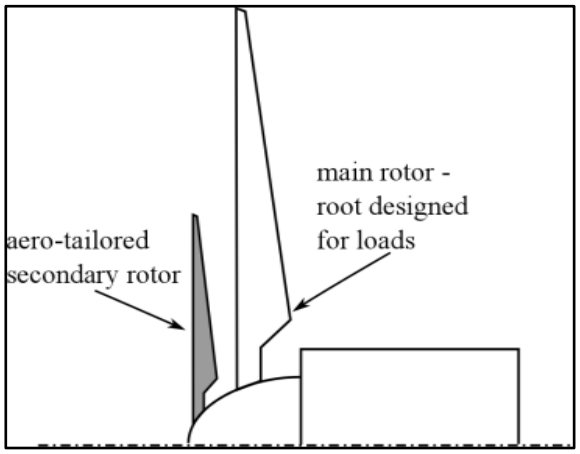
Step #5: Shape & Develop Idea

- It took a year to get the first working piece of code … applied to one baseline geometry
- Performed several calculations to show trend prediction capability
- Refined several things in the software for robustness, speed, ease of use etc.
- Published 2 years after we had all the results … Proprietary concerns!
- Finally, GE Aviation adopted it in their design process! Success at last

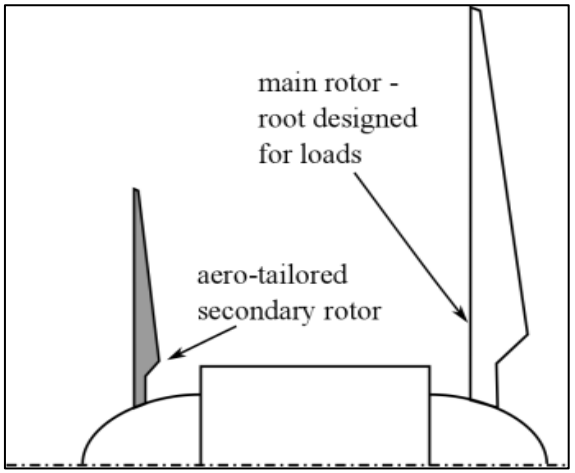
EXAMPLE #2

Dual Rotor Wind Turbine

Project with Prof. Hui Hu in Aerospace Engineering



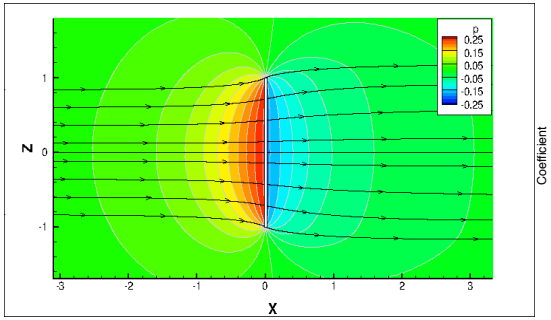
Idea: mitigate root and wake losses by using an aux. rotor in HAWTs

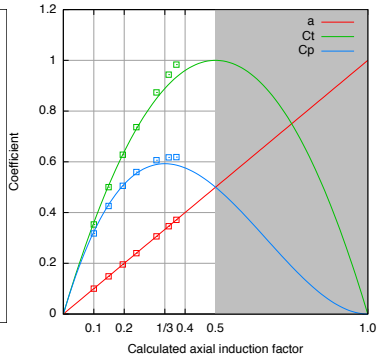


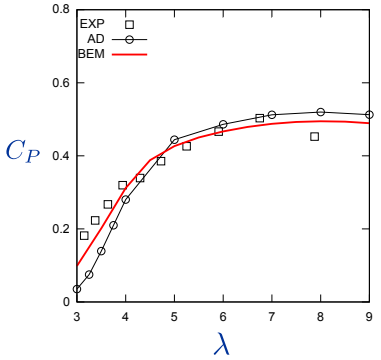
Step #1: Gathering Raw Material

Material:

- Working on root loss quantification
- Lit. review + analyses → root loss ~ 5% performance
- Patent / literature search → other concepts (VGs, etc.)
- Developed methods to analyze aerodynamic performance of wind turbines







Certainly didn't spend enough time on this!

Step #2: Digestion of Gathered Mtl.

Loads
Manufacturing
Transportation

Rotor geometry that is aerodynamically inefficient in the root region

Loads are inevitable … consequence of producing torque

- Aero performance ← torque force
- Loads ← thrust force

Another means to harness energy near the root region?

Steps #3 & #4: The Idea

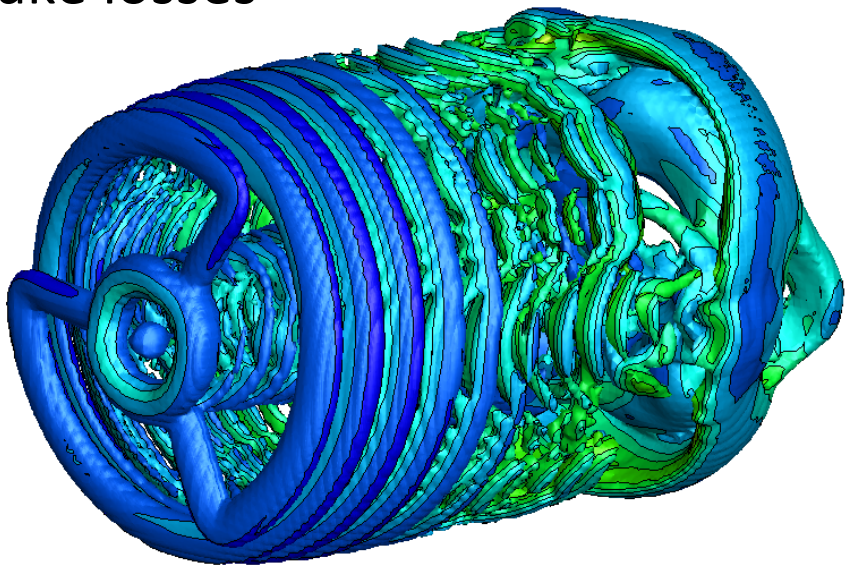
→IDEA: use 2 rotors:

Rotor #1: Extracts energy near the hub

Rotor #2: Extracts energy in the outboard region

Another potential use:

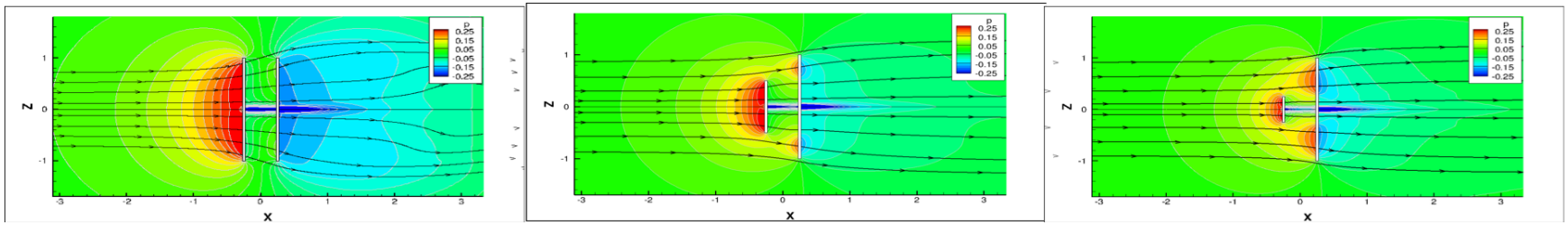
tailor wake shear → mitigate wake losses



Step #5: Shape & Develop Idea

- Carried out back-of-the-envelope analyses
- Developed numerical framework to design dual-rotor turbines
- Discussed with Prog. managers at Iowa Energy Center (IEC) & NSF
- Seed money from IEC … proposal to NSF under evaluation

  … hope will lead to a working product one day



A TIP

Become a Weed

Become hardy as weeds …

… 1 idea gets thrashed, smile & work towards another

Conclusion

- Read, observe, & analyze a lot!
  - When you think you are done, spend 2X more effort
  - A *tall pyramid requires a very wide base*

- Understand the raw material
  - Rephrasing helps
  - Identify gaps / opportunities
  - Think hard … till your head hurts

- Focus on the above two … ideas will come
  - Roger Federer: *"I try to give myself opportunities*"

- When you get an idea, nurture it … but, don't get too hung up!
  - Be ready to throw away ideas upon critical, objective review. You have many more in store!
  - *Become a weed*!