Planning for Work in Mathematical Sciences at a National Lab
(or what I wish I’d known in grad school)

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∞ General
∞ Overview of needs in mathematical sciences / roles for mathematicians
∞ What you can do now – resources / programs for students

IMA, 26 March 2010, Minneapolis
Infrared Image of Atlantis Launch
Hubble Space Telescope

Image from the HST
Major areas at NASA

• See [www.nasa.gov](http://www.nasa.gov) and center pages
• Space
  – E.g., Shuttle and station, Solar system, Universe
• Aeronautics
  – E.g., fundamental aeronautics, Next Generation (Air) Transportation
• Science
  – E.g., Earth, materials, bioastronautics, astrobiology

• Impacts on daily life via technology transfer and educational outreach
**General setting**

- Research, development, systems analysis, systems engineering
  - As a rule, all activities, even in fundamental research, have an application in mind

- Traditionally, the majority of staff are engineers and scientists
  - Injecting math is interesting, challenging, great fun
  - Translation of discipline specific language to math amenable to solution is one of the most important skills to acquire for a mathematician

- In R&D, a mathematician might consider two roles
  - Become an expert in a discipline or an application and stay with it, in essence becoming a scientist or an engineer with great math skills
  - Remain a generalist and contribute to research and development in many applications and disciplines
Where is math? (explicit, implicit, potential)

- Some aerospace disciplines are traditionally math intensive
  - E.g., computational fluid dynamics, structural analysis, multidisciplinary optimization
  - Example of current math: numerical PDE, nonlinear optimization, computational science

- Other disciplines have traditionally relied on experience, expertise, heuristic approaches and evolutionary development
  - E.g., design, transportation systems
  - Example of current approaches: simplified disciplinary models, rule-based and agent-based simulations, evolutionary algorithms, scenario-based analysis

- Fact: systems are growing in complexity and novelty (e.g., vehicles) and some current systems are reaching saturation (e.g., transportation)
  - Evolutionary, experience-based approaches alone are insufficient for (radically) new concepts
  - A major need for mathematical methods and mathematicians
  - N.B. This need not always explicitly recognized and expressed
Some important areas ready for math

- IMO, the most important: predictive modeling (of everything) with quantified uncertainty/confidence
  - Numerical simulations are ubiquitous & growing
  - How much are the answers worth?
  - When can computational models really replace experiments?

- Modeling, analysis, design, and optimization of very large complex systems with autonomous but interacting players (“systems of systems”, “complex adaptive systems”), such as transportation system
  - Boundaries unclear; predictability unclear
  - Such systems have never been designed; have to start
  - “System thinking”: e.g., green
  - How do we construct proofs about such systems (e.g., how do we prove that a more automated air traffic control system is safe?)

- What do we do with the coming hardware?
- (For specific problems, see web site)
Useful skills to develop

• (Assuming your technical mathematical skills are a given)
• Eliciting problem description from subject experts to formulate a mathematical problem
  – Subject experts may think in different terms, almost in a different language; up to the mathematician to translate
  – “People skills” are a good thing
• Working to a strict deadline
  – Depending on the area, some deadlines are stronger than others;
  – Regardless of the area, accountability is necessary
• Patience and flexibility when offering new methods
  – Mathematicians are often naïve about the realities of applications
  – Engineers are (mostly!) justifiably cautious about new “recipes”
• Ability to work both in a team and alone
• Strong computing skills
• Writing well and writing proposals
Best advice – get some experience while still at school

- **Google NSPIRES and subscribe**
  - Your advisor may consider submitting a proposal in response to an NRA (NASA Research Announcement, competitive process), and include you as part of the team.

- **Google GSRP**
  - Three-year program, where your dissertation topic is of some interest to NASA; working with NASA advisor, in addition to your faculty advisor. Work at school during the year and have an opportunity to spend summers at NASA.

- **See LARSS at** [http://edu.larc.nasa.gov/larss/](http://edu.larc.nasa.gov/larss/)
  - Summer at NASA Langley Research Center working with a NASA mentor.