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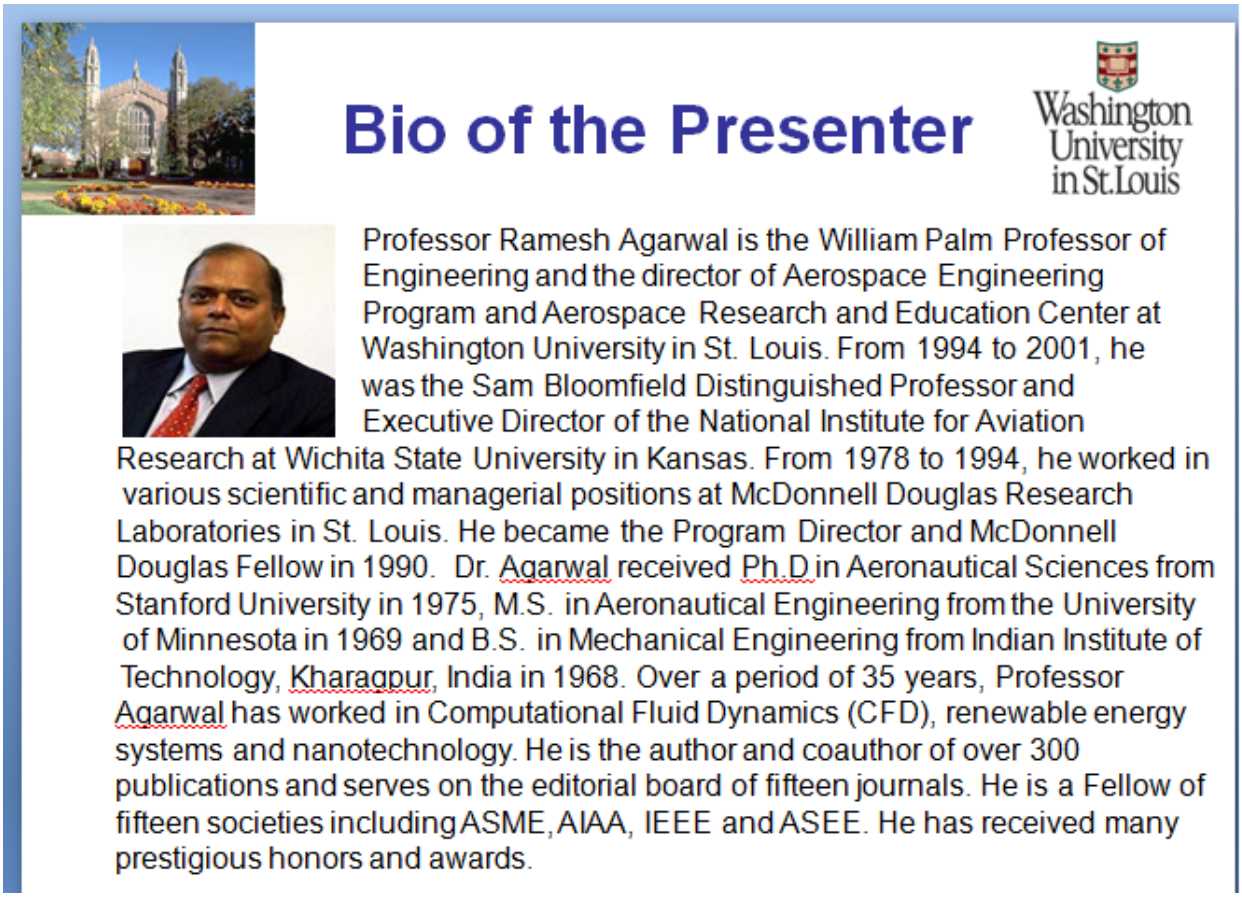
Introducing Sustainability d
in Engineering Education

Sustainable Product Design
in all Disciplines of Engineering
(Keynote)

Bio of the Presenter



Sustainability

- **"The effort to frame social and economic policy so as to preserve earth's bounty – its resources, inhabitants, and environments – for the benefit of both present and future generations. The old Native American proverb ---- We do not inherit the earth from our ancestors, we borrow it from our children."**

Frank. H.T. Rhodes, President Emeritus, Cornell University, in Chronicle of higher Education, 20 October 2006

Sustainability and
Human Welfare

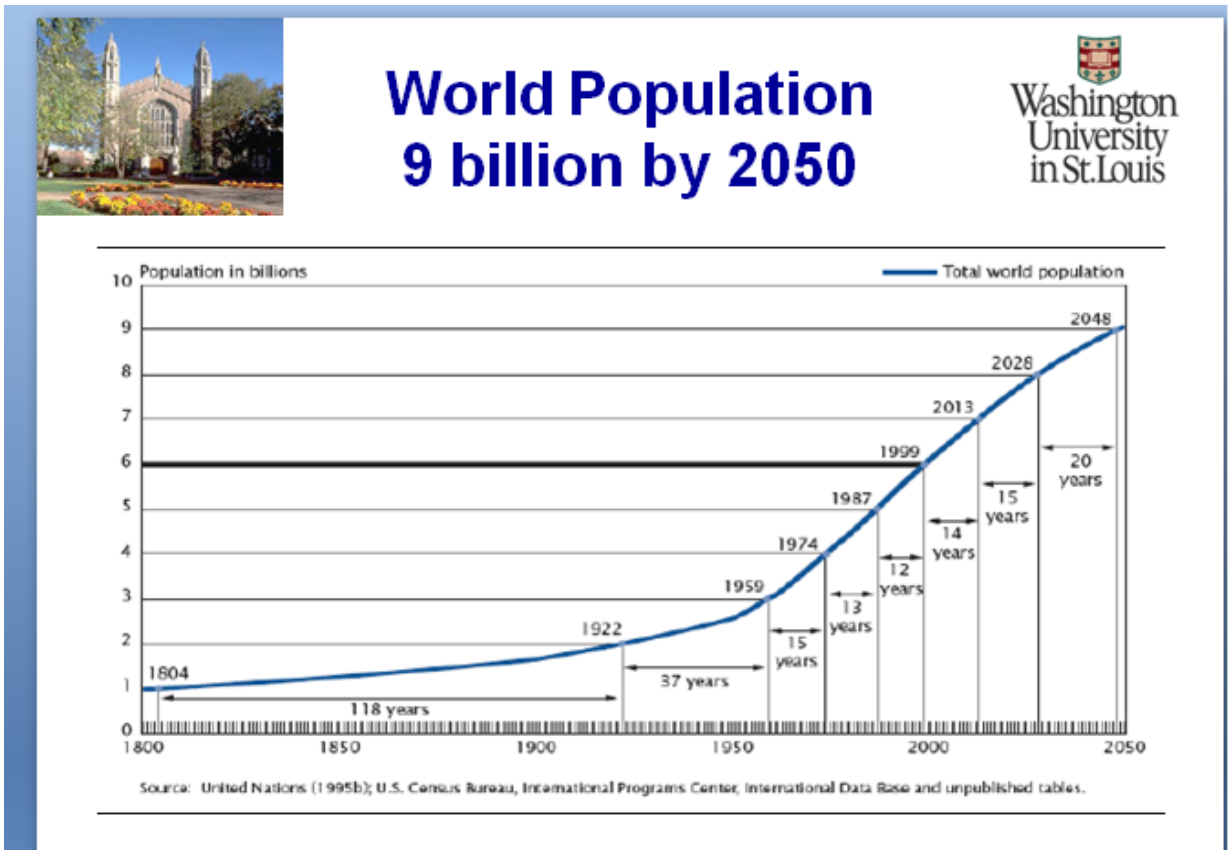
"As countries work to improve the well-being of their people, they risk by-passing the goal of sustainability.--- People are turning resources into waste faster than nature can turn waste back to resources. ---Humanity's 'ecological footprint' – the demand people place on the natural world- has more than tripled between 1961 and 2003."

James Leape, Director General WWF

Reuters, 24 October 2006

Population and
Consumption Statistics
1950-2000

- **Population Doubled**
- **Food Consumption Tripled**
- **Fossil Fuel Consumption Quadrupled**
- **Energy Consumption more than Quadrupled**



Challenges
for Sustained Improved Quality
of Life on Planet

U.N. Millennium Goals for Humanity

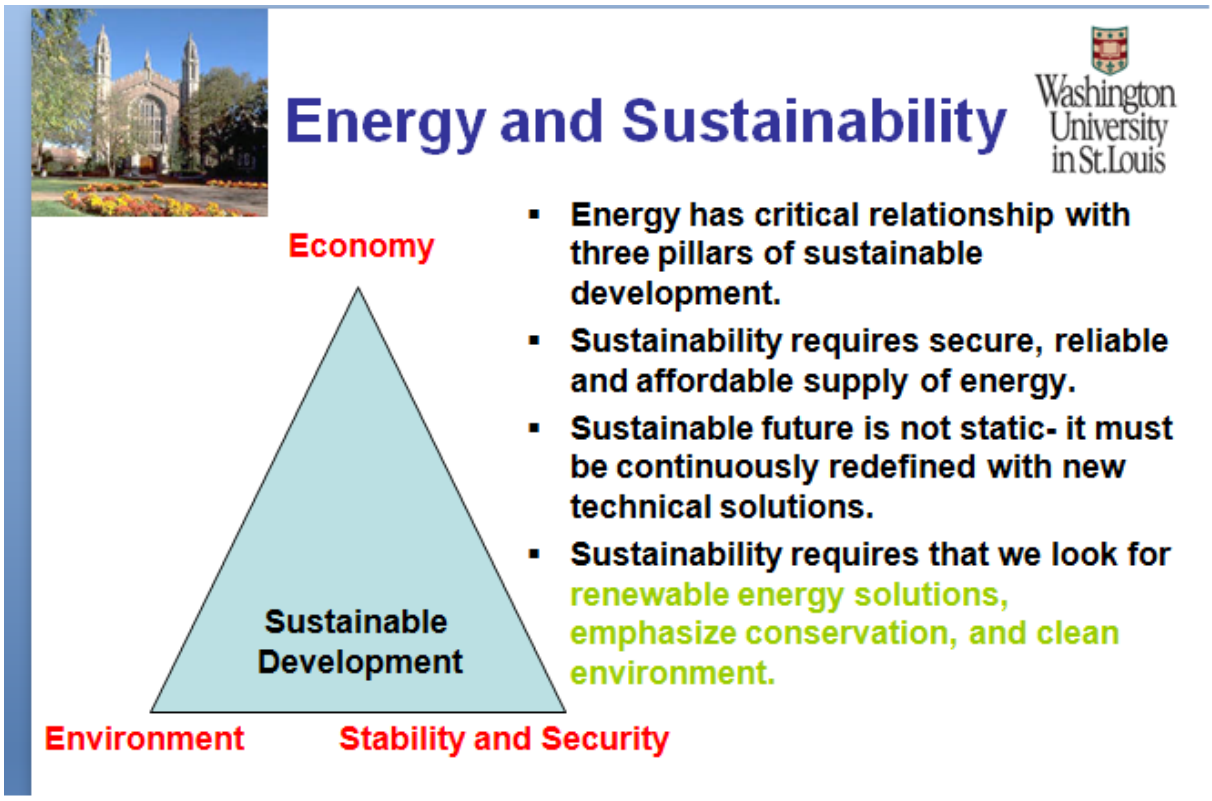
- **Water**
- **Food**
- **Health**
- **Education**
- **Poverty**
- **Environment**

- **Energy**
- **Democracy, Freedom and Security**

"All above require Science and engineering solutions"

Role of Engineer in Achieving Sustainable Development

- **In all disciplines of engineering, engineers are engaged in development and creation of products and services for consumers.**
- **The creation of products requires material, energy, water and other resources and results in hazardous and non-hazardous waste and emissions, which have adverse impact on environment.**
- **The resources are finite and their demand is increasing due to increase in population and expectations for better quality of life by 2/3 of humanity.**
- **For sustainability, the goal is to minimize the consumption of resources as well as to minimize the impact on environment.**



Product Design
for Sustainability (DfS)

- **Design for Sustainability means developing products with minimal or no environmental impacts – not 'eco' or 'green' products - but incorporating environmental considerations into good design practice for everyday products**

Product Design
for Sustainability

- **"Products can be considered as the embodiment of environmental harm caused by production, consumption and disposal."**

  - ***Eva Heiskanen, Finnish environmental economist***
- **It is estimated that 70% of a product's environmental impact is locked in at the design stage.**

Key Principles of DfS

- **Efficient design - keep the material and resource inputs (energy in particular) to a minimum.**
- **Cyclic design - design to enable materials to be continuously cycled through natural or industrial systems.**
- **Safe design - avoid toxic and hazardous substances and processes. Keep human health in mind as well as ecological impacts.**
- **Communications design - ensure product and packaging related communications are informative and accurate. Encourage responsible consumer behaviour.**

Example: Sustainable Transportation

- **Technologies for Sustainable Environmentally Responsible Air Transportation**
- **Technologies for Sustainable Environmentally Responsible Ground Transportation**

Environmentally Responsible Sustainable Aviation

- **Reduction in Energy Requirements**

- Reduce the Vehicle Mass Using High Strength Low Weight Materials (Advanced Composites)
- Innovative Aircraft Designs (e.g. BWB) and Technologies (e.g. high L/D)
- Innovative Engine Designs (e.g. P&W PurePower)
- NextGen Air Traffic Management (ATM)
- Changes in Aircraft Operations (Reduce MTOW and Range)
- Air-to-Air Refueling, Close Formation Flying, Tailored Arrivals

- **Reduction in GHG Emissions**

- Alternative Fuels (Bio-fuels, Synthetic Kerosene)
- Innovative Aircraft Designs (e.g. BWB) and Open Rotor Engines, Low NOx Combustors

- **Reduction in Noise**

- Innovative Aircraft Designs (e.g. Silent Aircraft SAX-40)
- Innovative Engine Designs (e.g. P&W PurePower)
- Airport Operations

Environmentally Responsible Sustainable Ground Transportation

- **Reduction in Energy Requirements**

- Reduce the Vehicle Mass Using High Strength Low Weight Materials
- Smooth the Operational Speed Profile
- Reduce Viscous Drag and Tires Contact Friction
- Efficiency Improvement by Automation
- Efficient Utilization of Infrastructure (Roads, Highways etc.)
- Improve Engine Efficiency, Hybridization

- **Reduction in GHG Emissions**

- Carbon - Based Fuels Synthesized from low carbon energy, e.g. Biofuels (Development of low cost catalysts capable of converting low-carbon energy into and out of forms amenable for portable storage)
- Portable Storage of Low Carbon Electricity (Development of Batteries with high energy density and stability)
- Hydrogen Production, Storage and Fuel Cells

Introducing Sustainability Concepts in Aerospace Courses at WUSTL

- **Aerospace Minor**
- **MEMS 2701 – Introduction to Aerospace Vehicles**
- **MEMS 5700 - Aerodynamics**
- **MEMS 5701 – Aerospace Propulsion**
- **MEMS 4302 – Aircraft Stability and Control**
- **MEMS 321 – Structural Behavior and Analysis**
- **MEMS 411 – Mechanical/Aerospace Design**

Inclusion of Sustainability in Aerospace Courses at WUSTL

- **MEMS 2701: the issues of environmental challenges such as noise and emissions are introduced in the context of current status and projected increase in noise and emissions in next twenty five years due to three fold increase in air travel (and as a result two fold increase in flying aircraft). If no new technologies are introduced and status-quo is allowed to remain, the aircraft emissions will contribute about 17-20% to total equivalent CO_2 emissions from all sources worldwide, which will not be acceptable because of worldwide efforts to reduce greenhouse gas (GHG) emissions due to their adverse impact on climate.**

Inclusion of Sustainability in Aerospace Courses at WUSTL

MEMS 5700: The concepts of drag reduction using active flow control and laminar flow wing are explained in the context of fuel savings and in turn in reducing the emissions. The design and performance of Honda Jet , which has natural laminar flow wings is compared with other conventional wing aircrafts in fuel efficiency. The basic concepts behind the newly emerging aircraft designs/configurations such as

Blended –Wing –Body, Silent Aircraft, Hydrogen Power Aircraft, Solar Power Aircraft, and Electric Aircraft are introduced as ways of reducing noise and emissions. One can design aircrafts which can be fuel efficient and reduce emissions. The contents of this course are closely coordinated with the aircraft design course MEMS 411.

Inclusion of Sustainability in Aerospace Courses at WUSTL

- **MEMS 5701: The concepts of high bypass engines and geared turbofans for improved efficiency are introduced. The alternative technologies such as fuel cells, solar power and hydrogen for propulsion are introduced. The alternative fuels such as biofuels and syngas fuels which have reduced emissions compared to currently used jet fuels are introduced. The use of chevron nozzles can reduce noise as well as special flight paths can change the directivity of noise near airports to help mitigate its effect on people living near airports. These ideas are brought to focus in this course.**

Inclusion of Sustainability in Aerospace Courses at WUSTL

- **MEMS 321: The concepts light weight materials such as Carbon Fiber Composites (CFC) and metal composites are introduced. Structural analysis of aircraft components such as wings and fuselage using these materials is introduced.**

Inclusion of Sustainability in Aerospace Courses at WUSTL

- **MEMS 411: The concepts of innovative aircraft designs such as BWB, Double Bubble etc. are introduced. The students are encouraged to come up with their own concepts. The project involves a team of 4 - 6 students.**

Conclusions

- **It is increasingly recognized that the concepts of sustainability should be introduced in engineering curriculum.**
- **Among many facets of sustainability, environmental sustainability has become one of the most important topics because of its direct impact on human health and welfare, and climate change.**
- **In this talk, we have tried to show how some of the environmental sustainability ideas can be introduced in the existing undergraduate aerospace engineering courses without changing the core content of the courses.**
- **We will be reporting our experience in this area in future ASEE conferences which may be beneficial to other engineering schools as they contemplate introducing sustainability in the curriculum.**