Mathematics in Industry Study Group (MISG) 2020

28 January – 1 February 2020

University of Newcastle, Australia

Co-Directors	Prof Natalie Thamwattana A/Prof Mike Meylan University of Newcastle
Public Lecture Speaker	Prof Ryan Loxton Curtin University
Administrative Support	Mrs Juliane Turner University of Newcastle
Technical Support	Dr David Allingham University of Newcastle

Internet Access

Wifi network: UoN_CONFERENCE

Password:

Enquiries: misg@newcastle.edu.au

Contents

1. Welcome

Welcome to the 2020 Mathematics in Industry Study Group (MISG). This is the first time the MISG has been held at the University of Newcastle, Australia. The Faculty of Science at the University of Newcastle is proud to support the MISG and the links we are making with industry.

We are very excited by the projects put forward by four companies, three of which are locally based in Newcastle. These four companies are **Lovells Springs, Safearth, Concrush** and **Hyper Q Aerospace**. We thank their support, their willingness to participate in the workshop and their recognition for the importance of mathematics/statistics to enhance their business design and operation. We hope that the variety of industry problems at the 2020 MISG will cater to a range of interests and expertise, and we hope to provide the solutions the companies are seeking.

We gratefully acknowledge the support from the University of Newcastle, the Faculty of Science and the University's Priority Research Centre: Computer Assisted Research Mathematics and its Applications (CARMA). Particularly, we would like to thank Mrs Juliane Turner from CARMA for her tremendous help in organising the workshop and also Dr David Allingham from CARMA for managing the website and for providing technical support to the workshop. We would also like to thank Mrs Leanne Murray and her marketing team from the Faculty of Science at the University of Newcastle for their help to advertise and publicise the MISG and the public lecture. We are also grateful to Professor Mark McGuinness (Victoria University of Wellington), Professor Troy Farrell (Queensland University of Technology), Associate Professor Amie Albrecht (University of South Australia) and Dr Neville Fowkes (University of Western Australia) for their helpful advice and comments in organising this workshop.

We would also like to acknowledge the support from the Conference Sponsorship Program of the NSW Department of Industry through the Office of the NSW Chief Scientist & Engineer and the ANZIAM Student Support Scheme.

Further, we are grateful to Professor Ryan Loxton from Curtin University for agreeing to give a public lecture at this year's event, and we thank the Hunter Branch of the Royal Society of NSW for the support of promoting the public lecture.

We trust that you will find this week enjoyable and productive. We hope that through this experience, you will gain something new in Newcastle (new knowledge, new skills, new ways of thinking, new networks, new friends, new opportunities,…). We are very much looking forward to seeing what will emerge from this week and beyond. Finally, we hope that you enjoy your stay in Newcastle and we hope to see you again here in 2021 and 2022.

Natalie Thamwattana and Mike Meylan

CARMA

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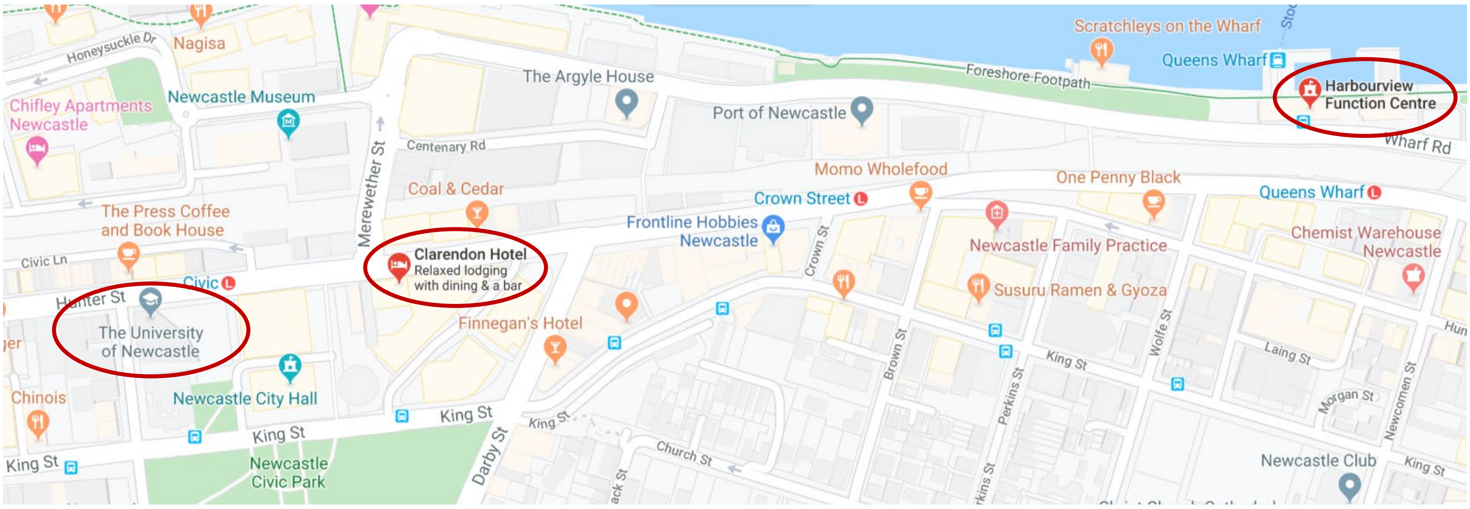
2. Workshop information and maps

MISG Workshop: **NewSpace (28 January – 1 February)**

Public Lecture: **Newcastle City Hall, Hunter Room (31 January at 5 pm)**

Welcome Reception: **The Clarendon Hotel, 347 Hunter Street, Newcastle (Tuesday 28 January at 6 - 8 pm)**

Workshop Dinner: **Habourview Function Centre, 150 Wharf Road, Newcastle (Thursday 30 January, drinks start from 6 pm)**



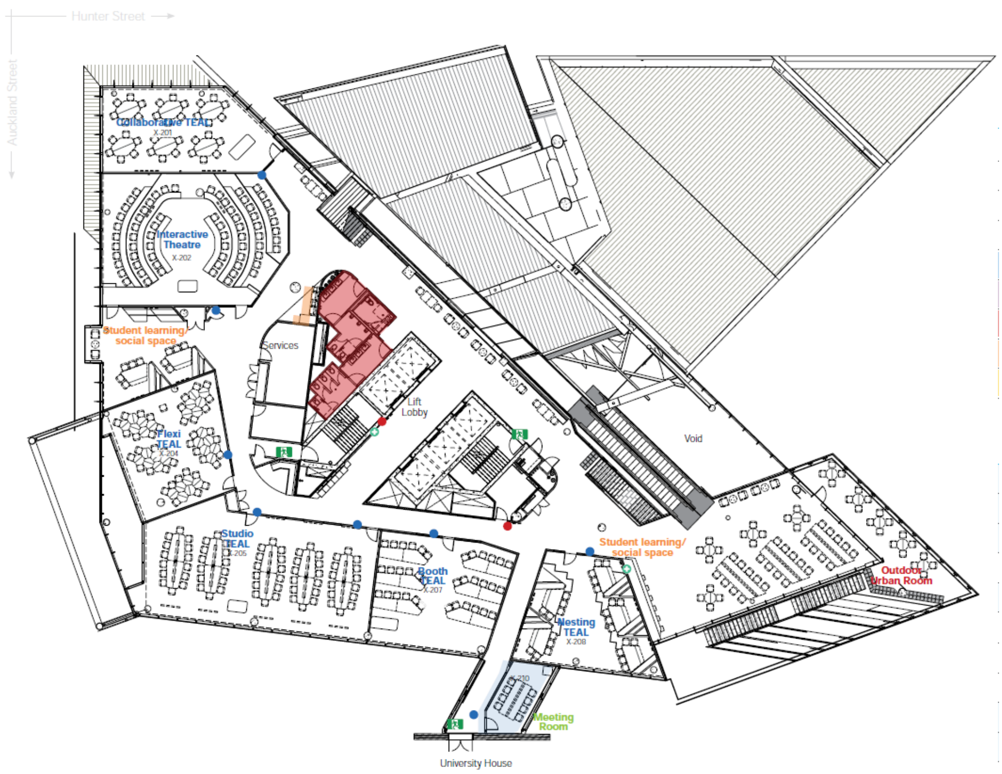
Map for recommended food and drinks in Newcastle city – page 21

NewSpace – First Floor X101

Tuesday 28 January, Thursday 30 January and Saturday 1 February

NewSpace – Second Floor X202, X204, X205, X207, X208

Tuesday 28 January – Friday 31 January



3. Programme

Tuesday 28th January
NewSpace, Room X101

8.00 – 9.00	Registration
9.00 – 9.15	Welcome from Pro Vice Chancellor, Faculty of Science, Professor Lee Smith
9.15 – 9.20	Welcome from Head, School of Mathematical and Physical Sciences, Professor Thomas Nann
9.20 – 9.30	Short address: MISG Co-Directors
9.30 – 10.00	**Lovells Springs – Industry Presentation**
10.00 – 10.30	**Safearth – Industry Presentation**
10.30 – 11.00	Morning Tea
11.00 – 11.30	**Concrush – Industry Presentation**
11.30 – 12.00	**Hyper Q Aerospace – Industry Presentation**
12.00 – 13.30	Lunch (not provided)
NewSpace, Rooms X202, X204, X205, X207, X208	
13.30 – 15.30	Project Breakouts
15.30 – 16.00	Afternoon Tea (Room X205)
16.00 – 17.00	Project Breakouts
18.00 – 20.00	Welcome Reception at the Clarendon Hotel

Wednesday 29th January
NewSpace, Rooms X202, X204, X205, X207, X208

9.00 – 10.30	Project Breakouts
10.30 – 11.00	Morning Tea (Room X205)
11.00 – 12.30	Project Breakouts
12.30 – 14.00	Lunch (not provided)
14.00 – 15.30	Project Breakouts
15.30 – 16.00	Afternoon Tea (Room X205)
16.00 – 17.00	Project Breakouts

Thursday 30th January
NewSpace, Rooms X101, X202, X204, X205, X207, X208

9.00 – 10.30	Project Breakouts
10.30 – 11.00	Morning Tea (Room X205)
11.00 – 12.00	**Mid-Week Project Updates (4 projects) Room X101**
12.00 – 13.30	Lunch (not provided)
13.30 – 15.30	Project Breakouts
15.30 – 16.00	Afternoon Tea (Room X205)
16.00 – 17.30	Project Breakouts

18.00 – 22.00	Workshop dinner at Harbourview Function Centre

Friday 31st January

NewSpace, Rooms X202, X204, X205, X207, X208

9.00 – 10.30	Project Breakouts
10.30 – 11.00	Morning Tea (Room X205)
11.00 – 12.30	Project Breakouts
12.30 – 14.00	Lunch (not provided)
14.00 – 15.30	Project Breakouts
15.30 – 16.00	Afternoon Tea (Room X205)
16.00 – 17.00	Project Breakouts
17.00 -17.30	Public Lecture Reception Drink at Newcastle City Hall
17.30 – 18.30	Public Lecture: Professor Ryan Loxton (Curtin University) at Newcastle City Hall

Saturday 1st February

NewSpace, Room X101

9.00 – 9.10	Short address: MISG Co-Directors
9.10 – 9.35	**Hyper Q Aerospace – Project Summaries**
9.35 – 10.00	**Concrush – Project Summaries**
10.00 – 10.30	Morning Tea
10.30 – 10.55	**Safearth – Project Summaries**
10.55 – 11.20	**Lovells Springs – Project Summaries**
11.20 – 11.30	Final Remarks
11.30	Workshop Closes
12.20	Bus to ANZIAM ECR Workshop

Breakout sessions

Project	Room
Lovells Springs	X202
Safearth	X204
Concrush	X207
Hyper Q Aerospace	X208

4. Public Lecture Information

Date: Friday 31 January 2020

Time: 5 pm for 5.30 – 6.30 pm

Venue: Hunter Room, Newcastle City Hall

Registration: Free (www.mathsinindustry.com)

Title: **Optimisation in Action – Unlocking Value in the Mining, Energy, and Agriculture Industries**

Abstract: Optimisation is a branch of applied mathematics that focuses on using mathematical techniques to optimise complex systems. Real-world optimisation problems are typically enormous in scale, with hundreds of thousands of inter-related variables and constraints, multiple conflicting objectives, and numerous candidate solutions that can easily exceed the total number of atoms in the solar system, overwhelming even the fastest supercomputers. Mathematical optimisation has numerous applications in business and industry, but there is a big mismatch between the optimisation problems studied in academia (which tend to be highly structured problems) and those encountered in practice (which are non-standard, highly unstructured problems). This lecture gives a non-technical overview of the presenter's recent experiences in building optimisation models and practical algorithms in the oil and gas, mining, and agriculture sectors. Some of this practical work has led to academic journal articles, showing that the gap between industry and academia can be overcome.

Speaker: **Professor Ryan Loxton**

Affiliation: School of Electrical Engineering, Computing, and Mathematical Sciences, Curtin University

Biography: Ryan Loxton is a professor and the discipline leader for mathematics and statistics in the School of Electrical Engineering, Computing, and Mathematical Sciences at Curtin University. Ryan's research interests lie in the areas of optimisation, optimal control, and data science. His work has been funded by the Australian Research Council (ARC), the Department of Industry, Innovation, and Science, and various industry partners, from small start-ups to large corporates. In particular, Ryan's ARC grants include two prestigious, highly competitive fellowships—an *Australian Postdoctoral Fellowship* during 2011–2014 and a current *ARC Future Fellowship* that runs until the end of 2021. His work focuses on using advanced mathematics to optimise complex processes in a wide range of applications such as mining, oil and gas, agriculture, and industrial process control. Ryan's algorithms underpin the Quantum software platform developed by Aurora Global for tracking, executing, and optimising shutdown maintenance operations at mine sites. Ryan is a passionate advocate for industry engagement and has worked extensively with industry where he has led demand-driven research projects with many companies, both big and small, including Woodside Energy, Vekta Automation, Fleetcare, and Global Grain Handling Solutions. Ryan was the recipient of the 2018 JH Michell Medal from the Australian and New Zealand Industrial and Applied Mathematics (ANZIAM) as the outstanding researcher of the year, and the 2014 West Australian Young Scientist of the year. Ryan currently leads the optimisation theme in the new *Australian Research Council's Industrial Training Centre on Transforming Maintenance through Data Science*, which is funded by a $3.9 million grant from the Australian Research Council plus matched funding from industry partners Alcoa, BHP Billiton, and Roy Hill.

5. Project 1 – Lovells Springs (Room X202)

Academics Moderators:	Mark McGuinness, Victoria University of Wellington Barry Cox, University of Adelaide
Student Moderator:	Balaje Kalyanaraman, University of Newcastle
Industry Representative:	Simon Crane http://www.lovellsauto.com.au/

Optimising furnace heat transfer

Lovells Springs is in its 80th year of business as a manufacturer and supplier of premium quality springs and suspension components to suit a broad range of applications for the automotive, agriculture, mining and railway industries.

The process of spring manufacture involves many stages, including oil quenching and tempering, shot penning and powder coating.

The most costly process of spring making is heating the steel. This process involves moving a fixed length of steel bars/rods (about 11-23 mm in radius) on refractory blocks into a furnace of approximately 1,000 C. These furnaces are custom built and are the heart of the operation. The heating and tempering furnaces are electronically controlled to precise temperatures which is the key to the production process. Once heated, the springs are made by hot coiling the steel rods.

The Challenge

Lovells Springs would like to understand and optimise their furnaces. Currently, they do not have any mathematical models of the process, and they believe that a mathematical model could make significant improvements, especially in the design of a new furnace.

In particular, Lovells Springs would like to develop mathematical models to achieve the following

- To assist in a new design of a furnace that allows the use of the waste/radiance heat which is exhausting from the furnace to heat the metal bars as they are moving into the furnace. Some of the questions Lovells Springs would like to answer include the optimal distance between each bar as a function of bar size and the optimal length of the furnace roof attached to the central heating chamber. This furnace roof enables the waste/radiance heat to flow and to heat the bars before their entering the main heating component of the furnace.

- Lovells Springs would also like to optimise their entire process of heating the steel. For this purpose, they require a model for the rate of heating of the bars, when they are heated by radiant heating in one part of the furnace and by convective heating in another. This will allow further optimisation of the process.

http://www.lovellsauto.com.au/profile.php

6. Project 2 – Safearth (Room X204)

Academics Moderators:	Geoff Pritchard, University of Auckland Glen Livingston Jr, University of Newcastle
Student Moderator:	Riya Aggarwal, University of Newcastle
Industry Representative:	Darren Woodhouse https://www.safearth.com/

Modelling Electrical Hazards

Safearth is a specialist electrical engineering group providing world-recognised expertise in safe power earthing systems. Safearth delivers comprehensive earthing solutions and management to safeguard people and infrastructure from electrical faults and lightning. Since being established more than 20 years ago, Safearth has designed and tested hundreds of earthing systems for high voltage installations, for power utilities, mines, oil and gas sites, and other industries.

The Challenge

Safearth would like to develop a more reliable understanding of electrical hazards to improve electrical safety standards in Australia.

It is well known that under strong enough voltages/currents, the human heart will stop beating, and this is the principle danger of receiving an electric shock. Such a process is known as ventricular fibrillation.

Currently, the safety standards in Australia specify a safe voltage/current, below which the effect is considered not to be life-threatening. In practice, the individual human response to voltages/currents varies greatly, and it would be better to develop a more sophisticated model in which the likelihood of injury was modelled. Due to the desire for large safety margins, the safe voltage must be one for which the probability of ventricular fibrillation is minimal. Thus the probability modelling become challenging due to the need to predict rare events.

Recently, Safearth has developed a more sophisticated safety model in which they proposed a calculation framework for quantifying the probability of the rare events of ventricular fibrillation around the critical voltage/current. They want to know if this model is the best way to approach the problem or if there are other better methods to solve this problem.

The model will be based on the available data on the human response to electricity and will use statistical methods to estimate the probability of, for example, the voltage below which the likelihood of death is less than one in a million (considered to be an acceptable safety margin). The analysis will use statistical and probabilistic methods.

https://www.safearth.com/

7. Project 3 – Concrush (Room X207)

Academics Moderators:	Melanie Roberts, Griffith University Brendan Florio, CSIRO
Student Moderator:	Fillipe Georgiou, University of Newcastle
Industry Representative:	Kevin Thompson http://www.concrush.com.au/

Effects of particle characteristics on dust dispersion

Concrush Pty Ltd was established in 2002 after recognising the need for a construction and demolition recycling facility in the Lake Macquarie region. Concrush Pty Ltd is a locally owned & operated business based at 21 Racecourse Road, Teralba NSW 2284.

Concrush provides cost effective disposal options for recycling of concrete, asphalt, bricks, pavers, roof tiles, wall and floor tiles, rock, sand, plasterboard and green waste for domestic households and commercial industry.

Concrush recycles these materials into specification and non-specification quality products such as; roadbase, drainage aggregates, pipe bedding and haunch, packing fines, decorative aggregates and mulches. These can be used within the civil and construction industries or for commercial, domestic and household applications.

Concrush's operations have the potential to generate or disturb dust. Concrush employs a mutli-pronged approach to minimising dust issues on site, and are committed to identifying and establishing best-practice strategies that will further reduce dust concerns.

The Challenge

To better understand dust generation and dispersion, Concrush would like to develop mathematical models:

- To understand the dispersion profile of different types of dust (cement, concrete/brick) generated from their site under various operational conditions, e.g. loading and tipping, crushing, and outside business hours. Concrush would also like to see a comparison of their scenario with other activities that also generate dust.

- To understand how particle characteristics (size and density) effect dust profiles at receiver locations. Concrush works predominantly with mixed products; therefore, their stockpiles are composed of a mix of different construction materials with different particle size and density profiles. Current approaches to modelling dust that are standard in the industry do not adequately consider the effect of particle size. Concrush would like to understand better how particle size and density affect dispersion. Will particle characteristics lead to a concentration of certain types of particles within dust at different locations?

- To determine the primary source of dust generation, whether it is the stockpiles of crushed up materials or the crushing machine or the road that light and heavy vehicles are moving in and out of the site so that if necessary, they can provide the protective cover to the right source to protect the dust from dispersion.

To assist in the development of accurate mathematical models, Concrush will provide data on the site layout (GIS information), monitoring data and conditions in which data are sampled, expected particle sizes and particle distribution for materials at the crusher, in the stockpiles and on the road.

8. Project 4 – Hyper Q Aerospace (Room X208)

Academics Moderators:	Graeme Hocking, Murdoch University Winston Sweatman, Massey University
Student Moderator:	Benjamin Maldon, University of Newcastle
Industry Representatives:	Peter Batten and Jim Azar https://www.hyperqaerospace.com/

Aerodynamics and control of next generation electric rotorcraft

Hyper Q Aerospace is driving a disruptive change in the understanding of helicopter aerodynamics and its implementation through the development of a hybrid electric rotorcraft.

This aircraft will use electric axial flux motors to rotate the rotorhead and attached rotor blades. The configuration will eliminate the need for gearboxes, transmissions and drive shafts as they currently exist in conventional helicopter design. Using an electric drive will offer a far more responsive RPM control of the rotorhead.

The rotorcraft will use small servomotors to replace the helicopter swashplate. This project will allow the functionality of a helicopter swashplate to be broken apart so that the properties of blade pitch angle control and rate of change of blade pitch angle become independent.

This project will enable Hyper Q Aerospace to build potentially the fastest helicopter style rotorcraft in the world.

Configuration

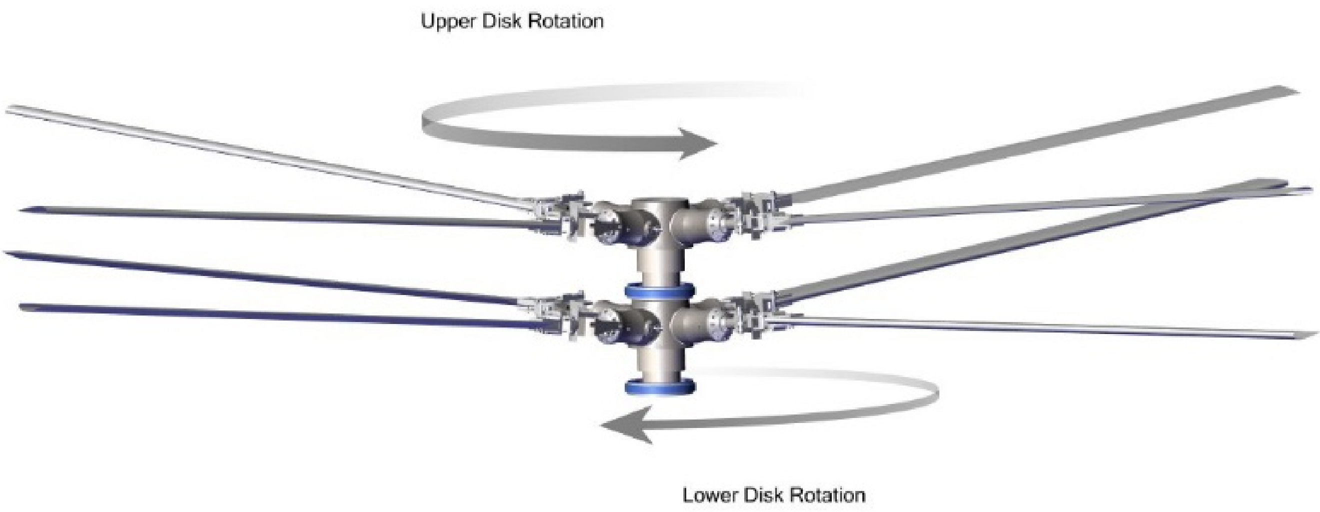
The rotorhead design is coaxial. Blade length is approximately 3m giving a rotor disk size of about 6.5m.

Typical angular velocity is 600RPM. Hyper Q Aerospace's design, however, will operate at angular velocities between about 250 RPM and 1500 RPM.

Aircraft velocity will vary from 0 to 300 kts or 550 km/hr.

Disk separation will be about 0.5m.

Concept Drawing

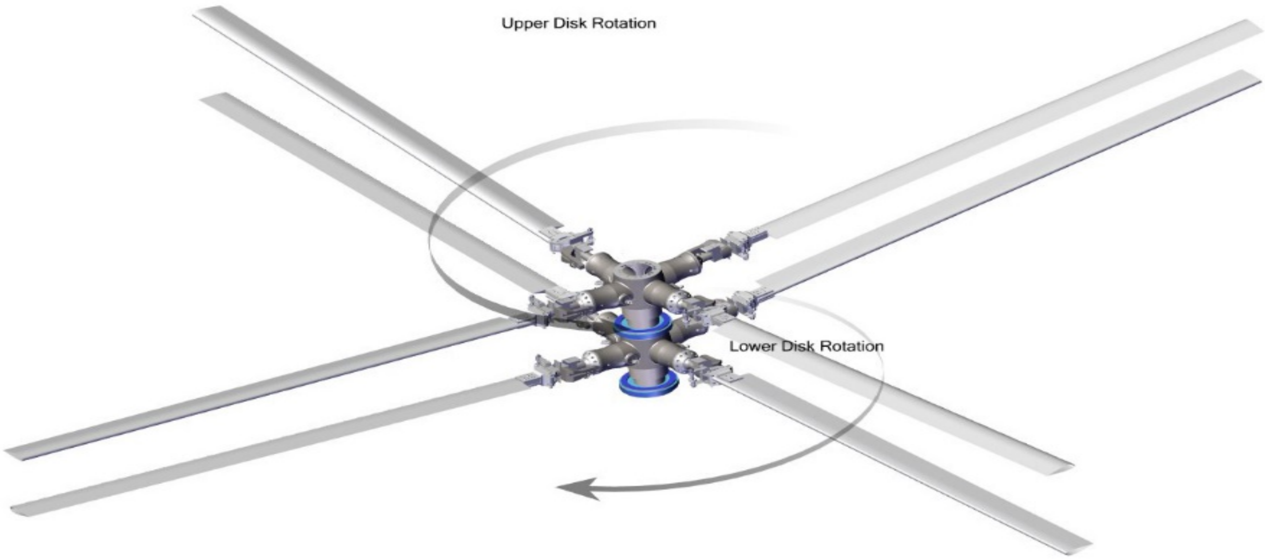


Aerodynamics

As the rotor blades rotate, they generate lift. This lift is created by a lower pressure on the upper side of the blade. The faster the blade spins, the greater the lift created. The amount of lift can be derived from the general lift (L) equation

$L = C_L \, 1/2 \, \rho \, V^2 \, S$

https://en.wikipedia.org/wiki/Lift_(force)



For helicopters, typical blade profiles can be described by standard aerofoils such as NACA 0012, NACA 0015.

From this data, it is possible to consider a point source as the calculus summation of all elemental chord slices of the blade to resolve the value and location of the centre of lift for a given blade at a particular angle of attack and rotational velocity.

If the aircraft is in equilibrium, i.e. in the hover, the total lift can be calculated by summing the lift created by each blade attached to the disk hub. This lift will be equal to the weight of the helicopter.

As the aircraft begins to move away from the hover, the value of lift is altered due to the change in the velocity of air over the blade. For the blades moving into wind, the advancing blades, the value of lift will increase. For the blades traveling in the same direction as the resultant airflow, there will be a reduction of lift. However, from the lift equation, it can be seen that the relationship to velocity is squared. Therefore there will be more lift generated the faster the aircraft goes for a given blade angle of attack.

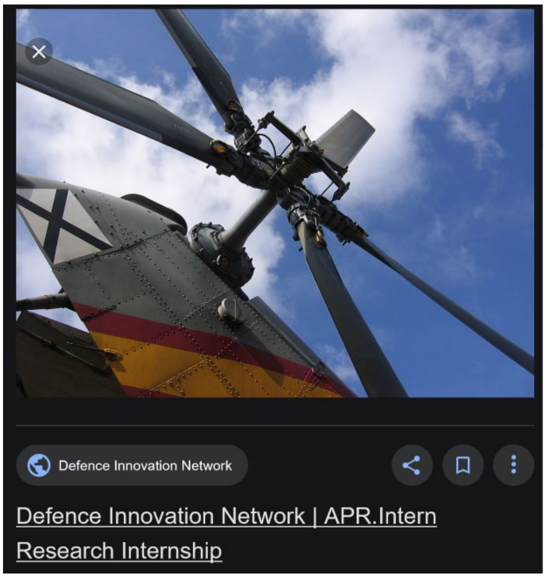
The Challenge

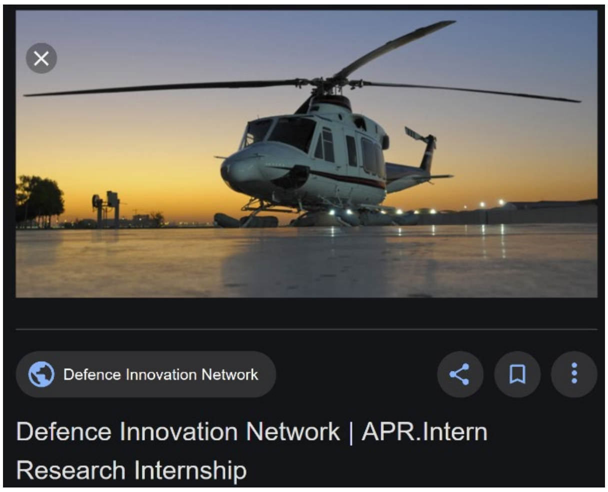
As our rotorcraft design will operate at a variable range of angular velocities:

1. What is the effect on the lift as the blades on the upper and lower disk cross each other at various angular velocities? Is aerodynamic bump a problem?
    a. Variables:
        i. Angular velocity

        ii. Upper to Lower disk displacement
        iii. Blade load/Angle of attack

2. What harmonic effects occur
    a. For each blade as velocity changes;
    b. For the entire rotor disk with multiple blades;
    c. Between rotor disks; and
    d. At blade crossing.
    e. Variables:
        i. Angular velocity
        ii. Upper to Lower disk displacement
        iii. Blade load/Angle of attack
3. Are there specific angular velocities that should be avoided?
4. What combination of angular velocity and blade pitch angle will generate the lowest noise footprint?





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See you again at MISG 2021

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