The Integrator

INCOSE North Star Chapter

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North Star Newsletter

INCOSE North Star Newsletter Communication

This month's article, entitled *A Brief Tutorial on Aircraft Survivability,* although focused on the aircraft domain, appears to be quite translatable to the medical device, ground combat, and other domains. Please let us know if you are able to visualize a cross-over application by sending comments to Eileen.Arnold@BAEsystems.com. Eileen Arnold, Editor

Online Principles of Systems Engineering Course
More information and online registration is available at: http://register.cce.umn.edu/Course.pl?sect_key=183696&web_sec=&cmp_cd=TUCL. For questions, please contact Mike Amidon, College of Continuing Education at amido001@umn.edu or (612) 624-7261.

Systems Engineering at its Best!

A Brief Tutorial on Aircraft Survivability

The general term **aircraft survivability** refers to the capability of an aircraft to avoid or withstand hostile environments, including both man-made and naturally occurring environments, such as lightning strikes, mid-air collisions, and crashes. The more traditional discipline known as **system safety** attempts to minimize those conditions known as hazards that can lead to a mishap in environments that are not made hostile by man. Thus, together, the system safety and survivability disciplines attempt to maintain safe operation and maximize the survival of aircraft in all environments in both peacetime and wartime.

Aircraft combat survivability (ACS) is the capability of an aircraft to avoid or withstand a man-made hostile environment. Survivability is mathematically measured by $P_{S,}$ the probability the aircraft survives an encounter (combat) with a man-made hostile environment.

Two factors affect an aircraft's survivability – its susceptibility and its vulnerability.

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Chapter President's Corner

John Palmer, U of Minnesota, and
Neill Radke, Cummins, 2009 Co-Presidents

Another action packed year has come and gone for the North Star Chapter and its friends and members. With a most successful Christmas Holiday Party at Jax Café on 12 December, an exciting year has ended. At over 40, the average monthly meeting attendance for 2009 was a new record. To a certain extent, this probably reflects the current high unemployment situation and illustrates the added value of our meetings in providing a networking opportunity. However, we believe it is also indicative of the increasing interest, particularly with commercial industry, in systems engineering and its benefits. As CNNMoney.com indicated in its 2009 selection of the 50 Best Jobs in America, Systems Engineering is number one! The ability of well managed systems engineering to improve company competitiveness by turning out better products with a stronger bottom line is being more widely recognized every day. The mission of INCOSE to continue spreading the word while systematically improving the tools and processes is making a significant difference. With strong emphasis on Systems Engineering certification, more and more practicing Systems Engineers are being recognized as professionals with the concurrent improvement in their own competitiveness. It is the basic mission of the North Star Chapter to continue furthering all these gains in the Twin Cities area. The chapter Strategic Plan has been applied in developing a meeting program for 2010 that we believe will be even more interesting and informative than 2009! All we need to make it successful is your participation and support. Join us regularly to make 2010 an even more successful year! To get more involved, please contact:

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Neill Radke at <nradke@hotmail.com> or
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Susceptibility is the likelihood of being detected, identified, and hit by an enemy or, alternately, the inability of an aircraft to avoid (the guns, approaching missiles, exploding warheads, air interceptors, radars, and all of the other elements of an enemy's air defense that make up) the man-made hostile mission environment. The more likely an aircraft on a mission is hit by one or more damage-causing mechanisms generated by the warhead on a threat weapon (e.g. warhead fragments, blast, and incendiary particles), the more susceptible is the aircraft. Susceptibility can be measured by the probability the aircraft is hit by one or more damage mechanisms, P_H. Thus, Susceptibility = $P_{H.}$

Vulnerability is a measure of the effects of being hit by a weapon or alternately, the inability of an aircraft to withstand (the hits by the damage-causing mechanisms created by) the man-made hostile environment. The more likely an aircraft is killed by the hits by the damage mechanisms from the warhead on a threat weapon, the more vulnerable is the aircraft. Vulnerability can be measured by the conditional probability the aircraft is killed given that it is hit, $P_{K|H}$. Thus, Vulnerability = $P_{K|H.}$

An infrequently used term is **Killability** which is the inability of the aircraft to both avoid and withstand the man-made hostile environment. Thus, killability is the ease with which the aircraft is killed by the enemy air defense. Killability can be measured by the probability the aircraft is killed, P_K. Killability is given by the joint probability the aircraft is hit (its susceptibility) and it is killed given the hit (its vulnerability). Thus, $P_K = P_H P_{K|H}$. Killability = Susceptibility • Vulnerability.

If the threat weapon contains a high explosive (HE) warhead with proximity fuzing, the subscript H for a hit is replaced with an F for warhead fuzing.

Aircraft combat survivability is mathematically related to the aircraft's killability, or the combination of its susceptibility and vulnerability, by the equation $P_S = 1 - P_K = 1 - P_H P_{K|H.}$

Survivability = 1 - Killability = 1 - Susceptibility • Vulnerability

Thus, an aircraft's combat survivability is enhanced when its killability is reduced. The killability of an aircraft is reduced when the susceptibility and the vulnerability of the aircraft are reduced.

An aircraft's **Susceptibility** in a hostile environment is dependent upon the following:

- The probability the enemy is able to detect the aircraft, P_D
- The probability the enemy can identify the aircraft if detected, $P_{I/D}$
- The probability the enemy can launch a weapon if the aircraft is identified, $P_{L/I}$
- The probability the launched weapon can hit the aircraft, $P_{H/L}$

Thus, aircraft **Susceptibility** is given mathematically by the equation

$$P_H = P_D \times P_{I/D} \times P_{L/I} \times P_{H/L}$$

Aircraft combat survivability is given mathematically by the equation

$$P_S = 1 - P_H P_{K|H} = P_D \times P_{I/D} \times P_{L/I} \times P_{H/L} \times P_{K|H}$$

Aircraft Survivability can be enhanced by reducing its susceptibility to being hit and its vulnerability if it is hit. Susceptibility reductions are achieved through reduced aircraft signatures, flying tactics and profiles (speed, high or low altitude, terrain following/avoidance, high maneuverability, etc.), counter measures (jamming, spoofing, etc). Vulnerability reductions are achieved through armor plating around critical components, structural strengthening/hardening, fire suppression systems, redundancy of critical components, etc. Survivability may be measured relative to encounters with individual threats or a group of threats on a mission.

John C. Muehlbauer, PhD, PE, CSEP

WELCOME, NORTH STAR NEW MEMBERS!

Name	Company	Title
Jeremy Aaby	LMCO	
Katherine Anderson	Medtronic	
Joe Armenta	LMCO	
Karyn Bratcher	Medtronic	
Jeffery Chinn	LMCO	
Melissa Clark	Medtronic	
Sue Davison		Consultant
Yanina Grinberg	Medtronic	
Rick Hoyme		
Jaene Hylander	Medtronic	
Peter Lucking	GDC4S	SE
LaTeska Newberry	LMCO	
Kurt Nordstrom	Care Fusion	
Scott Norling	LMCO	
Gordon Perkins	Medtronic	Prin FW Eng
Joe Robertson	St Jude Med	Sr. Engineer
Robin Webster	LMCO	SI&T
Peter Werness	Beckman Coulter	Sen Staff SE

North Star Chapter Website
http://www.incose.org/northstar