Data Sets from Ground Testing to Build Trust in the Prognostic Algorithm which Predicts Remaining Flying Time for NASA's Edge 540 All Electric UAS

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The data set contains HIRF tests experiment data conducted on the Edge 540

Experimental Description:

A small electric unmanned aerial vehicle (e-UAV) is been used in this study. The e-UAV is a 33% sub-scale version of the Zivko Aeronautics Inc. Edge 540 T tandem seat aerobatic aircraft. This vehicle has been actively used by researchers at NASA LaRC to facilitate the rapid deployment and evaluation of remaining flying time prediction algorithms for electric aircraft since 2010.

Two types of tests were conducted: 1.) ground-based testing (to ascertain that the vehicle meets safety standards and to conduct experiments other than for RUL determination); and 2.) real flight tests off a local airstrip. The ground-based testing of Edge 540 T hardware and software was performed by strapping the vehicle down in the LaRC Electromagnetics and Sensors Branch High Intensity Radiated Fields (HIRF) test chamber. Besides allowing to run UAS radio frequency emissions test (see [1]), the HIRF chamber also provides protection in case of catastrophic release of the propeller. The airplane was placed upon expanded-polystyrene blocks centered within the chamber. The aircraft powertrain with propeller was operated with the vehicle anchored using a steel cable to the chamber wall. Its motor and actuators were operated from another room (effectively acting as a virtual ground station) using the same remote control radio that is used in flight tests. There was visual contact through a video feed.

Measured aircraft states, battery SOC estimates, and remaining flying time estimates were broadcast to the virtual ground station over a wireless downlink. The virtual ground station also had an uplink interface that enables the aircraft's autopilot to autonomously follow a given flight plan in chamber testing. This autopilot hardware-in-the-loop interfacing capability is discussed in [2].

All data in the experiments were collected with the aircraft operating in manual/auto control mode (Ref Table 1 for details). Aircraft propeller RPM, estimated battery SOC, and predicted flying time remaining were displayed to system operators by the virtual ground station in near real-time. The motor throttle was commanded using the control radio by a manual operator, who read the RPM display from the ground station. The operator adjusted the remote control throttle to maintain the target values for the time duration as determined by the flight plan described in Section 3.2. The test proceeded until a 28% SOC condition was indicated on the ground station display for the lowest battery. Battery current draw was then stopped and powertrain batteries

were allowed to rest for approximately one hour. The battery terminal voltages at rest were used compute an empirical approximation of ending battery SOC.

Note: This document only refers to the HIRF test data The same batteries were used in the Flight experiments which are listed as a separate dataset entry (These will be added to the PCOE repository).

Reference:

[1] Ely, J., Koppen, S., Nguyen, T., Dudley, K., Szatkowski, G., Quach, C., Vazquez, S., Mielnik, J., Hogge, E., Hill, B. & Strom, T. (2011). "Radiated Emissions From a Remote-Controlled Airplane - Measured in a Reverberation Chamber, NASA/TM-2011-217146.

[2] Verification of a Remaining Flying Time Prediction System for Small Electric Aircraft. Edward F. Hogge, Brian M. Bole, Sixto L. Vazquez, Jose R., Annual Conference of the Prognostics and Health Management, PHM 2015

Parameter names explained for each of the data structure's.

Files: HIRF 5- HIRF 13

Field Structure with following parameters

t - time

RPM – Revolutions Per Minute

FMC – Forward Motor Controller Sensor

AMC – After Motor Controller Sensor.

LLF20V Lower Left Front – Battery Voltage

ULA20V Upper Left After – Battery Voltage

LRF40V – Lower Right Front – Series Combined Voltage

URA40V – Upper Right After – Series Combined Voltage

LRF20V – Lower Right Front – Battery Voltage

URA20V – Upper Right After – Battery Voltage

LLF20C – Lower Left Forward – Battery Current

ULA20C – Upper Left After – Battery Current

LRF40C – Lower Right After – Series Combined Current

URA40C – Upper Right After – Series Combined Current

LLF20T – Lower Left Front – Temperature

ULA20T – Upper Left After – Temperature

LRF40T – Lower Right Front – Series Combined Temperature

URA40T – Upper Right After – Series Combined Temperature.

Files: All remaining tests

Field Structure with following parameters

t - Time

RPM – Revolutions per minute

LLF20V Lower Left Forward - Battery Voltage

ULA20V Upper Left After – Battery Voltage

LRF40V – Lower Right Forward – 2 Battery Set Voltage

URA40V – Upper Right After – Battery Set Voltage

LRF20V – Lower Right Forward – Battery Voltage

URA20V – Upper Right After – Battery Voltage

LLF20C – Lower Left Forward – Battery Current

LRF40C – Lower Right Forward – Battery Set Current

ULA20C – Upper Left After – Battery Current

URA40C – Upper Right After – Battery Set Current

LESCIM2 – Left ESC current sensor

RESCIM1 – Right ESC current sensor.

LLF20T – Lower Left Forward – Battery Temperature

ULA20T – Upper Left After – Battery Temperature

LRF40T – Lower Left Forward - Battery Set Temperature

URA40T – Upper Right After – Battery Set Temperature

BHM - Battery Health Monitoring

Table 1: Chamber Experiment

		Batteries used during each run				
Test #	**Type**	**LL**	**LR**	**UL**	**UR**	**Test Type**
SET 1						
HIRF5	Manual	34	36	37	38	Envelope Expansion
HIRF6	Manual	NA	NA	NA		debugging
HIRF7	Manual	21	22	25	29	debugging
HIRF8	Manual	NA	NA	NA		debugging
HIRF9	Manual	23	24	25	26	No Load
HIRF10	Manual	27	28	29	30	RPM cal
HIRF11	Manual	NA	NA	NA		Only Parasitic Load
HIRF12	Manual	31	32	33	34	No Load
HIRF13	Manual	36	37	38	39	debugging
SET2						
HIRF14	Manual	21	22	25	26	Parasitic Load
HIRF15	Manual	36	37	38	39	Parasitic Load
HIRF16	Autopilot	31	32	33	34	No Load
HIRF17	Manual	36	37	38	39	No Load
HIRF18	Manual	31	32	33	34	No Load
HIRF19	Manual	21	22	25	26	Parasitic Load
HIRF20	Autopilot	36	37	38	39	Parasitic Load
HIRF21	Manual	31	32	33	34	Parasitic Load
SET3						
HIRF22	Manual	36	37	38	39	Parasitic Load
HIRF23	Manual	21	22	25	26	Parasitic Load
HIRF24	Manual	27	28	29	30	No Load
HIRF25	Manual	31	32	33	34	Parasitic Load
HIRF26	Manual	36	37	38	39	Parasitic Load
HIRF27	Manual	23	24	25	26	No Load
HIRF28	Manual	31	32	33	34	Parasitic Load
HIRF29	Manual	21	22	29	30	Parasitic Load
HIRF30	Manual	27	28	25	26	No Load
HIRF31	Manual	31	32	33	34	Parasitic Load
HIRF32	Manual	36	37	38	39	Parasitic Load
HIRF33	Manual	23	24	25	26	No Load
HIRF34	Manual	27	28	29	30	Parasitic Load
HIRF35	Manual	31	32	33	34	Parasitic Load
HIRF36	Manual	36	37	38	39	No Load
SET5						
HIRF37	Manual	27	28	29	30	Parasitic Load

HIRF38	Manual	36	37	38	39	No Load
HIRF39	Manual	23	24	25	26	Parasitic Load
HIRF40	Manual	31	32	33	34	No Load
HIRF41	Manual	36	37	38	39	Parasitic Load
SET6						
HIRF63	Manual	36	37	38	39	No Load
HIRF64	Manual	23	22	33	34	No load
HIRF67	Manual	31	32	33	34	No load
HIRF68	Manual	27	28	29	30	No load
HIRF69	Manual	27	28	29	30	No load
HIRF71	Manual	27	28	29	30	No load
HIRF72	Manual	21	22	29	26	No load
HIRF73	Manual	36	37	38	39	No load
HIRF74	Manual	31	32	33	34	No load
SET7						
HIRF75	Manual	27	28	29	30	No load
HIRF76	Manual	31	32	23	24	No load
HIRF77	Manual	36	37	38	39	No load
HIRF78	Manual	40	41	42	43	No load
HIRF79	Manual	44	45	46	47	No load
HIRF80	Manual	42	43	48	49	No load
HIRF81	Manual	48	49	42	43	No load

NA : These battery identification numbers are currently not available and will be updated once we receive them.