TELEMETRY GROUP

SPECIAL REPORT

SENSOR NETWORK REQUIREMENTS: REPORT OF FINDINGS

WHITE SANDS MISSILE RANGE
REAGAN TEST SITE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER
ELECTRONIC PROVING GROUND
HIGH ENERGY LASER SYSTEMS TEST FACILITY

NAVAL AIR WARFARE CENTER WEAPONS DIVISION, PT. MUGU
NAVAL AIR WARFARE CENTER WEAPONS DIVISION, CHINA LAKE
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION, PATUXENT RIVER
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NAVAL UNDERSEA WARFARE CENTER DIVISION, KEYPORT

30TH SPACE WING
45TH SPACE WING
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AIR ARMAMENT CENTER
ARNOLD ENGINEERING DEVELOPMENT CENTER
BARRY M. GOLDWATER RANGE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

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TELEMETRY GROUP

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PREFACE

This report presents the work performed by the Telemetry Group (TG) of the Range Commanders Council (RCC) under task TG-98. The information contained in this report will support future standardization tasks and can be beneficial to ranges that acquire data from sensor-based test platforms such as aircraft and ground vehicles. This report addresses the standardization for sensor networks. If standardized, the sensor and network interfaces, systems, and components will have common characteristics, thereby enhancing data exchange and interoperability.

Technical characteristics and performance matrixes for wireless and wired sensor networks are provided herein. The matrixes are based upon known existing and forecasts of future measurement systems requirements.

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ACRONYMS

AAC	Air Armament Center
AC	aircraft
AFFTC	Air Force Flight Test Center
AFRL	Air Force Research Laboratory
AIC	Airborne Icing Tanker
ATC	Aberdeen Test Center
ATTC	Aviation Technical Test Center
DAU	data acquisition unit
FT	flight Test
Hz	Hertz
iNET	Integrated Network Enhanced Telemetry
IRIG	Inter-range Instrumentation Group
ML	missile launcher
NAVAIR	Naval Air Systems Command
NAVAIR CL	NAVAIR, China Lake
NAVAIR PR	NAVAIR, Patuxent River
RB	Refueling Basket
RCC	Range Commanders Council
TAS	Test Article Segment
TASWG	Test Article Segment Working Group
TG	Telemetry Group
TM	telemetry
TmNS	Telemetry Network System
UNK	unknown
VIT	Vehicle Instrumentation/Transducer (committee)
YPG	Yuma Proving Ground

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SENSOR NETWORK REQUIREMENTS: REPORT OF FINDINGS

1. Objective

The Integrated Network Enhanced Telemetry (iNET) project is aimed at defining standards associated with a variety of systems, interfaces, and components of a data acquisition system on board the test article. The Range Commanders Council (RCC) Telemetry Group (TG), Vehicle Instrumentation/Transducer (VIT) Committee is actively participating in iNET efforts with a goal to incorporate much of this work into the Inter-range Instrumentation Group (IRIG) 106 Telemetry Standards document. The current iNET effort and architecture definition incorporate the interface of data acquisition units (DAUs) to the iNET Telemetry Network System (TmNS). The "back-end" of the DAUs and the method of data acquisition are not addressed by iNET. Task TG-98 investigated the characteristics of a back-end sensor network (wired or wireless) to determine the capability and appropriateness of interfacing with a DAU or some other network gateway to the iNET TmNS. The requirements and characteristics will provide preliminary information to determine the extent of any standardization needs in this area.

2. Scope of Task

The scope of this task includes the current and projected needs of sensor network applications. These networks may be wired or wireless. For the purpose of this task, the following definitions apply:

a. Sensor. A device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. The terms sensor and transducer are often used interchangeably. For the purpose of this task, the term sensor can mean:
   (1) A transducer (such as an accelerometer).
   (2) A device that may integrate one or more transducers and other functions such as power and signal conditioning into a self-contained unit.

b. Smart Sensor. A smart sensor exhibits one or more of the following features:
   (1) Self-identification
   (2) Smart calibration/compensation
   (3) Electronic data sheets

c. Dumb Sensor. A dumb sensor cannot analyze or act on its measurements; it just provides measurements for remote processing.

d. Sensor network. A system of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions such as temperature, sound, vibration, pressure, motion, or other physical phenomena at different locations.

3. Task TG-98 Committee Members

The TG Vehicular Instrumentation/Transducer (VIT) Committee members include:

a. Steve Musteric, Air Armament Center (AAC): Task Lead
b. Mike Mando, Aviation Technical Test Center (ATTC)
c. Brian Keating, Naval Air Systems Command, Patuxent River (NAVAIR PR)
d. Lorin Klein, AAC
e. Robert Neufeld, Air Force Flight Test Center (AFFTC)
f. Bill Stange, Air Force Research Laboratory (AFRL)
g. Karl Simon, AAC
h. Ray Faulstich, NAVAIR PR
i. Teresa Telles, Naval Air Systems Command, China Lake (NAVAIR CL)
j. Karl Lumpkins, Yuma Proving Ground (YPG)
k. Sam Marderness, Aberdeen Test Center (ATC)

4. Data Collection

To facilitate data collection, the VIT Committee developed and used the Sensor Network Application Survey shown at Appendix A. Each active VIT Committee member was requested to provide input to the survey and each was encouraged to seek inputs from other personnel at their respective test centers. The initial request for inputs was sent soon after the Task Proposal was approved by the RCC Technical Representatives (Tech Reps). The suspense date for inputs was October 31, 2009.

5. Findings and Deliverables

To address the feasibility of standardization within sensor networks, it was necessary to characterize the nature of these networks. Network characterization is not a trivial task because of the wide variety of test articles, physical parameters of interest, potential network structures, and data throughput requirements. The reader should note that the results of the survey represent a "snapshot in time."

The survey inputs showed that the main parameters of interest included the classic physical phenomena such as temperature, vibration, strain, pressure, and video. The desired network types included both wired and wireless. Sample rates requirements ranged from 10 Hz to 20K Hz. The maximum number of sensor nodes ranged from a single node to 20,000 nodes. The summary of survey inputs is shown at Appendix B.

6. Conclusions

The results of the survey and discussions with members of the T&E community across the Services indicated the existence of a variety of sensor network requirements. While there may be some commonality in basic measurement requirements, each application's uniqueness (size, weight, power, spatial distribution of sensors, etc.) makes a case for a tailored solution. As part of the TG meeting in August 2008, the VIT Committee invited members of industry to

present solutions. Based on these presentations and inputs to the survey, it appears that the development of standards relative to sensor network structure may not be feasible at this time. The VIT Committee does not recommend that resources be devoted to this effort until either demand increases or a dominant technology emerges. The standards-development effort within the iNET Test Article Segment (TAS) Working Group (TASWG) will continue to address the interface between sensor network data acquisition units (DAUs) and the TAS.

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APPENDIX A

TG-98 SURVEY FORM

TASK TG-98: SENSOR NETWORK APPLICATION SURVEY

Please complete a separate survey for each distinct sensor network application

Part 1 – Administrative	
Name:	**Job Title:**
Organization/Range	**RCC Affiliation:**
Phone:	**E-Mail Address:**

Part 2 – Mission Description (General)

a. iNET Mission Environment: (*Please highlight all that apply using the **Text Highlighter** tool*)

Aeronautical	Ground Vehicles	Munitions	Missiles/PGMs	Other

If "Other," please describe:

b. Test Article: *(Aircraft structure, suspension equipment, control surfaces, etc.)*

c. Parameter of Interest To Be Measured: (*Please highlight all that apply using the **Text Highlighter** tool*)

Vibration	Temperature	Pressure	Strain	Acoustics	TSPI	Optical Energy	Other

If "Other," please describe:

Part 3 – Mission Details

Mission Description: *(Please describe the test scenario. Ex: The purpose of the mission is to characterize the vibration environment on key parts of the aircraft structure or store in captive carriage configuration. Data of interest is to be measured and recorded throughout the mission…)*

Part 4 – Data Sampling

Sample Rate: *(Please describe the rate at which data must be sampled and the aggregate data throughput required, if applicable):*

Part 5 – Network Structure

a. **For this application, which type of network is better suited** (*Please highlight using the **Text Highlighter** tool*)

Wired	Wireless

b. **Please describe the network structure envisioned for this application** *(star, mesh, bus, etc.)*
c. **How many distinct nodes are required to adequately meet mission needs?** *(Specify a range)*
d. **Are "smart" sensors desired for this application?**
e. **Please describe the network protocol envisioned for this application** *(Bluetooth, ZigBee, IEEE 802.11, etc.)*
f. **Please characterize the data acquisition method envisioned for this scenario, including installation method and location:**

Part 6 – Telemetry

a. **For this application, is the measured data needed real time?**
b. **If the data must be telemetered, describe the envisioned interface between the DAU and the telemetry device:**

Part 7 – Additional Information

Please provide any other pertinent information about this application:

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APPENDIX B

TECHNICAL CHARACTERISTICS/PERFORMANCE MATRIXES

TABLE B-1. TECHNICAL CHARACTERISTICS/PERFORMANCE MATRIX: WIRELESS SENSOR NETWORKS

Physical Parameter of Interest	Regime of Interest	Test Article	Application	Sensor Nodes Needed per Network (Max)	Max Sample Rate (Hz)	Real-time TM? (Y/N)	Test Range	Submitted by:
Vibration	0-50 Hz	ML	FT[1,3]	4	400	Y	AAC	Musteric
Position	UNK	AC	FT[2]	20	100	Y	AFFTC	Golacksen
Temperature	UNK	AC	FT[2]	20	100	Y	AFFTC	Golacksen
Temperature	UNK	AC	FT[4]	16	10	Y	AFFTC	Heaton
Pressure	UNK	AC	FT[4]	16	10	Y	AFFTC	Heaton
Temperature	UNK	AC	FT[5]	2	2000	Y	ATTC	Mando
Strain	UNK	AC	FT[3,5]	2	2000	Y	ATTC	Mando
Strain	UNK	RB	FT[3,6]	3	100	Y	NAVAIR	Keating

********** LEGEND AND FOOTNOTES **********

AC Aircraft
FT Flight test
ML Missile launcher
RB Refueling Basket
UNK Unknown

1. Flutter flight test (FFT), F-16
2. Measurement of control surface position and displacement + temperature
3. Measurement at various equipment installations and locations for different AC flight test conditions
4. KC-135 Airborne Icing Tanker (AIT)
5. Measurement of loads and response of rotor head components
6. Measurement of strain response on KC-130 Refueling Basket

TABLE B-2. TECHNICAL CHARACTERISTICS/PERFORMANCE MATRIX: WIRED SENSOR NETWORKS

Physical Parameter of Interest	Regime of Interest	Test Article	Application	Sensor Nodes Needed per Network (Max)	Max Sample Rate (Hz)	Real-time TM? (Y/N)	Test Range	Submitted by:
Pressure	UNK	AC	FT[1]	2	100	N	ATTC	Mando
Vibration	UNK	AC	FT[2]	UNK	1000	Y	ATTC	Mando
Strain	UNK	AC	FT[2]	100	1000	Y	ATTC	Mando
Vibration	UNK	AC	FT[3]	~5	~200	Y	ATTC	Mando
Temperature	UNK	AC	FT[3]	~5	~200	Y	ATTC	Mando
Pressure	UNK	AC	FT[3]	~5	~200	Y	ATTC	Mando
TSPI	UNK	AC	FT[3]	~5	~200	Y	ATTC	Mando
Video		AC	FT[4]	20	UNK	Y	AFFTC	Golackson
Rate/Attitude		AC	FT[4]	20	UNK	Y	AFFTC	Golackson
Vibration	UNK	AC	FT[3]	UNK	20,000	Y	AFFTC	Vuong
Temperature	UNK	AC	FT[3]	UNK	UNK	Y	AFFTC	Vuong
Pressure	UNK	AC	FT[3]	UNK	UNK	Y	AFFTC	Vuong
Strain	UNK	AC	FT[3]	UNK	UNK	Y	AFFTC	Vuong
Acoustics	UNK	AC	FT[3]	UNK	20,000	Y	AFFTC	Vuong

********** LEGEND AND FOOTNOTES **********

AC Aircraft
FT Flight Test
UNK Unknown

1. Pressure field survey of engine inlets and exhausts, and other aerodynamic appendages
2. Flight load survey of helicopter airframe loads
3. Helicopter performance and handling quality testing; also systems integration testing
4. Measurement of control surface position and displacement