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RESEARCH PRESSURE INSTRUMENTATION

FOR

NASA SPACE SHUTTLE MAIN ENGINE

NASA CONTRACT NO. NAS8-34769

MODIFICATION NO. 5

MONTHLY REPORT

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

June 1984

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HONEYWELL INC.
SOLID STATE ELECTRONICS DIVISION
CONTRACT NO. NAS8-34769
MODIFICATION NO. 5

RESEARCH OF PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE

Monthly R & D Progress Report June 1984 - Report No. 9

A. Technical Progress and Plans

- See attachment 'A'

B. Schedule

- See attachment 'B'

C. Status of Funds

	LBM
Total Baseline Plan	$407,350
Total Funded	$300,000
Cost Incurred to 8/01/84	$246,021
Inception to Date Plan	$204,635*
Estimate at Completion	$407,350

D. Estimated percent of physical completion: 60%

E. At the present time the comparison of the cumulative costs to the percent of physical completion does not reveal any significant variance requiring explanation.

* These numbers for April and May were incorrectly reported. The reported and corrected numbers are as follows:

	April	May
• Reported	$211,286	$217,600
• Corrected	$196,896	$203,070

ATTACHMENT 'A'

RESEARCH PRESSURE INSTRUMENTATION
FOR
NASA SPACE SHUTTEL MAIN ENGINE
HONEYWELL, INC.

1.0 Introduction and Objective

The first phase of this contract (Tasks A and B) resulted in a highly successful demonstration in April 1983 at the MSFC of Honeywell's breadboard feasibility model of a silicon Piezoresistive Pressure Transducer suitable for SSME applications.

The purpose of Modification No. 5 of this contract is to expand the scope of work (Task C) of this research study effort to develop pressure instrumentation for the SSME. The objective of this contract (Task C) is to direct Honeywell's Solid State Electronics Division's (SSED) extensive experience and expertise in solid state sensor technology to develop prototype pressure transducers which are targeted to meet the SSME performance design goals and to fabricate, test and deliver a total of 10 prototype units.

SSED's basic approach is to effectively utilize the many advantages of silicon piezoresistive strain sensing technology to achieve the objectives of advanced state-of-the-art pressure sensors in terms of reliability, accuracy and ease of manufacture. More specifically, integration of multiple functions on a single chip is the key attribute of this technology which will be exploited during this research study.

The objectives of this research study will be accomplished by completing the following major tasks:

1. Transducer Package Concept and Materials Study

   Three transducer design concepts will be generated and analyzed for the SSME application and materials/processes will be defined for the research prototype transducer design.

2. Silicon Resistor Characterization at Cryogenic Temperatures

   The temperature and stress properties of a matrix of ion implanted piezoresistors will be characterized over the temperature range of -320°F to +250°F.

3. Experimental Chip Mounting Characterization

   The mechanical integrity of chip mounting concepts will be evaluated over temperature, pressure and vibration.

4. Frequency Response Optimization

   This task is a paper study which will specify and analyze an acoustic environment for which transducer frequency response can be determined and optimized.

5. Prototype Transducer Design, Fabrication, and Test

This major task will use the results generated in Tasks 1 through 4 above to design and develop a research prototype pressure transducer for the SSME application and will culminate in the delivery of 10 transducers, 5 each for the ranges of 0 to 600 psia and 0 to 3500 psia. This task is subdivided into the following five areas:

- Feasibility Evaluation of Transducer Concept
- Prototype Transducer Design
- Prototype Transducer Fabrication and Test
- Prototype Qualification
- Prototype Delivery.

6. Reports

Honeywell will submit monthly progress reports during the period of the contract; a final report will be provided at the completion of the contract.

The format of this report will be to discuss the work performed for this reporting period and the plans for the next reporting period for each of the major tasks outlined above.

2.0 Work Performed and Plans

2.1 Transducer Package Concept and Materials Study.

This task was completed per plan during January 1984.

2.2 Silicon Resistor Characterization at Cryogenic Temperatures.

This task was completed in May 1984.

2.3 Experimental Chip Mounting Characterization

2.3.1 Work performed in June

- Continued a literature search on the properties of silicon nitride. The search is broken down into four major categories, i.e.,

  - General physical-mechanical properties
  - Cryogenic behavior
  - Forming/shaping properties
  - Methods of joining silicon nitride to other materials

- The status of this literature search is as follows:

  - Ten articles have been received and reviewed.
  - These articles contain considerable data on the physical-mechanical properties at room and elevated temperatures and on the forming/shaping properties of silicon nitride.
  - No data has been found on the behavior of silicon nitride at cryogenic temperatures. This situation supports the need to initiate a materials test program on silicon nitride at cryogenic temperatures, i.e., consistant with the cryogenic fluids required for the SSME.
  - To-date, these joining methods have been identified, i.e.,

    -- Ti/Cu -- This is an acceptable metallization for our application. It is reported to be better than a Cr/Cu metallization. A 500°C post-process anneal is reported to improve the adhesion of the metal to the silicon nitride.

    -- Ti/Cu/Be -- This metallization is good for the brazing of silicon nitride-to-silicon nitride; however, the melting point is too high for our application.

    -- Diffusion and Glass Bonding -- These are effective joining methods; however, they too, require higher temperatures than what our application can tolerate.

- The design work for the following fixtures was completed:
  - Vibration testing (4,000g's).
  - High pressure testing.
  - High pressure leak checking.
- These sensor piece-parts were received:
  - Silicon nitride subassemblies.
  - Lapped and polished pyrex washer.
  - Lapped and polished cover-glass window.

  All the piece-parts have been received so sensor assembly can be started.
- The assembly of "dummy" sensor chips to the pyrex washer was started.

2.3.2 Plans for July

The plans are as follows:

- Complete the assembly the Experimental Sensors.
- Complete the fabrication of these fixtures:
  - Vibration testing (4,000g's).
  - High pressure testing.
  - High pressure leak checking.
- Start testing sensor asemblies as they are completed.
- Continue literature search on silicon nitride with special emphasis on joining methods.

2.4 Frequency Response Optimization

This task was completed per plan in February 1984.

2.5 Temperature Sensor Network Concept Study.

This task was deleted when the contract was negotiated.

2.6 Prototype Transducer Design, Fabrication and Test

2.6.1 Feasibility Evaluation of Transducer Concepts.

2.6.1.1 Define/Finalize Concept for Feasibility Transducer.

This task was completed per plan as reported in May. The sensor chip design was presented in that report. Though not mentioned specifically, the sensor package will be the same as that developed for the Experimental Sensor. (Re: previous Monthly Reports.) Clearly, that design will be modified to reflect insights gained from the evaluation of the Experimental Sensor.

This task is closed.

2.6.1.2 Feasibility Demonstration of Sensing Concepts.

.1 Work performed in June

- The mask fabrication was completed, and they were placed on the wafer processing line at our Colorado Springs facility.
- The silicon starting material was characterized for wafer thickness and staged in the wafer processing line. A permanent I.D. number was scribed on each wafer to support correlation of wafer properties and test results.
- A process spec, run card or traveler were prepared to support the processing of these wafers.
- Wafer processing was started at our Colorado facility.
- All sensor package piece-parts for the functional Feasibility Sensor models have been ordered except for the stainless steel housing and base. The later two items are machined parts and will be fabricated in our model shop. There is some risk associated with this approach; however, it is judged to be low enough to be acceptable. Furthermore, it is required in order to accommodate the lead times for these parts. These orders were placed on the basis of the piece-part design and drawings in-hand at this writing.

.2 Plans for July

The plans are as follows:

- Start the design of special assembly tooling to support the build of the Feasibility Sensor models.
- Finalize the decision regarding the fabrication of a new stainless steel housing and base or the modification and reuse of same from the Experimental Sensor models.

2.7 Miscellaneous

Russell Johnson and David Wamstad presented a paper at the "Advanced High Pressure O_2/H_2 Technology Conference" held at the Marshall Space Flight Center on June 27-29, 1984. The paper presented by Honeywell, Inc. was entitled "An Advanced Solid State Pressure Transducer for High Reliability SSME Application". A copy of the abstract is enclosed as Attachment 'C'.

3.0 Schedule -- See Attachment 'B'.

ATTACHEMENT B

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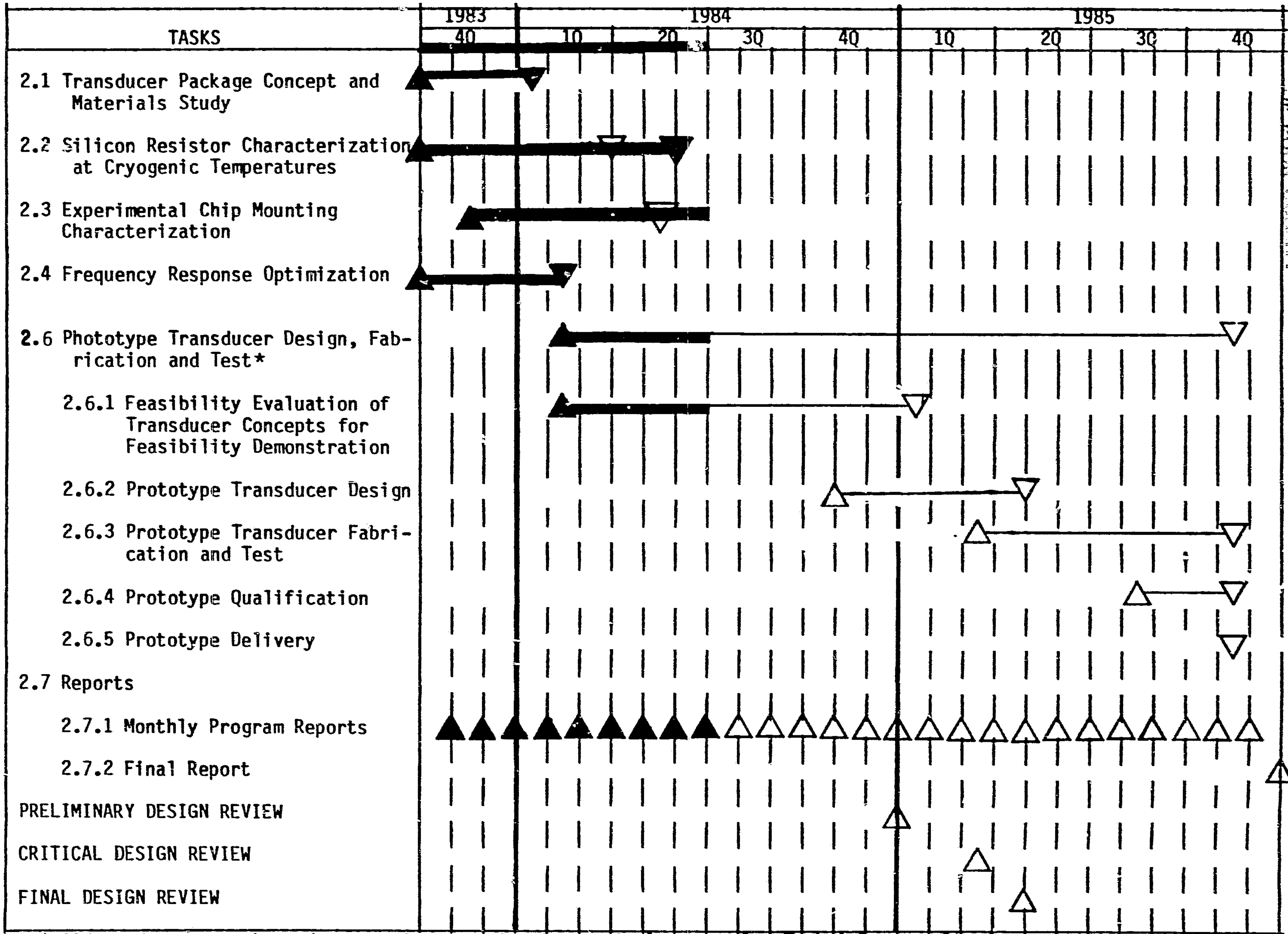
RESEARCH PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE SCHEDULE



* 12/83: Numbering changed to retain numbering in original proposal. Task 2.5 was deleted during contract negotiations

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ATTACHMENT 'C'

AN ADVANCED SOLID STATE PRESSURE TRANSDUCER

FOR HIGH RELIABILITY SSME APPLICATION

R. L. Johnson and D. B. Wamstad
Solid State Electronic Division
Honeywell, Inc.

The objective of this research project is to define and demonstrate new methods to advance the state-of-the-art of pressure sensors for the Space Shuttle Main Engine. This includes improved reliability, accuracy, cryogenic temperature operation and ease of manufacture.

This paper presents the results of the "Feasibility and Breadboard Demonstration Phase" and the current status of the "Research Development Prototype Follow-on Phase." A technology breakthrough utilizing silicon piezoresistive technology was achieved in the first phase. Excellent silicon sensor performance, at liquid nitrogen temperature, was successfully demonstrated at NASA/MSFC.

The follow-on phase is in process. A transducer design concept for the SSME application utilizes packaging materials with similar thermal coefficients of expansion and maintains the transducer seal primarily in compression. The package mechanical integrity will be tested to the SSME requirements for temperature (-252°C to +120°C), pressure (10K psi), and vibration (400 g's). The silicon chip design will provide dual sensing outputs with integrated compensating electronics. The silicon resistor ion implant dose was customized for the SSME temperature requirement. A basic acoustic modeling software program was developed as a design tool to evaluate the frequency response characteristics for the package design. Successful completion of this research project will provide ten prototype SSME Solid State Pressure Transducers for NASA testing.

The intrinsic attributes of silicon pressure sensor technology, such as small size, low mass, integratable electronics and reduced package complexity, all contribute to the attainment of the research objectives. The advancement in the state-of-the art of solid state pressure sensing technology, as achieved by this research project, will provide the technology base of future "Smart Sensors" for space vehicle applications.