United States General Accounting Office

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Report to the Honorable
Andy Ireland, House of Representatives

July 1989

DEFENSE CONTRACTING

Cost, Schedule, and Performance to Develop a Ground Power Generator System

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GAO

United States
General Accounting Office
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National Security and
International Affairs Division

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The Honorable Andy Ireland
House of Representatives

Dear Mr. Ireland:

In response to your requests, we are providing cost, schedule, and contractor performance information on two 1983 Air Force contracts for research and development of a ground power generator system. Your requests were based on an allegation by your constituent, Trilectron Industries of Palmetto, Florida, that the results of the research and development were not satisfactory, yet the Air Force proceeded to the production of the system in September 1988 with one of the two original contractors. Subsequently, your constituent and the other original contractor filed bid protests concerning the contract award for production. We issued a decision on this matter (Ingersoll-Rand Company; Trilectron Industries, Inc., B-232739, et al., Feb. 7, 1989, 89-1 CPD para. 124), which denied the protests.

In November 1982 the Air Force issued a request for proposals for research and development, also known as phase I, of an acquisition program involving a new ground power generator system. The system was to contain a generator cart and an air conditioner cart that would operate on the flightline, in a hangar, or in an aircraft shelter. The system was to provide electrical power, air start capability, and air conditioning for tactical aircraft undergoing pre- or postflight inspections and/or maintenance. The primary objectives of phase I were to develop the most fuel-efficient system, reduce significantly the noise level from that of existing equipment, improve the cooling capacity of the air conditioning system, and attain higher reliability and maintainability of the equipment.

Phase I was to be performed under dual contracts awarded to two contractors to conduct parallel research, design, development, and testing of their system designs. In December 1983 the Air Force awarded fixed-price contracts for research and development to Teledyne Continental Motors and Ingersoll-Rand Company. The Air Force planned a separate solicitation for production and procurement, known as phase II, at a later time. In September 1988 the production contract was awarded to Teledyne.

Results in Brief

Because of your constituent's concern about the phase I contracts, you asked us to review the cost, schedule, and contractor performance. Final cost of the research and development contracts totaled about $26.3 million. This amount includes net price increases of about $431,000, primarily for engineering changes. In addition, Ingersoll-Rand has a $1.7 million claim pending with the Air Force. Setbacks occurred at various stages of development and testing, which resulted in schedule revisions. As a result, phase I took 4 months longer than planned, but most of the delays were unrelated to contractor performance problems.

Various technical requirements were met in some instances and not in others. For example, both contractors met the noise requirements, but only one of the contractors met the 1983 and 1986 fuel consumption baseline requirements. Neither contractor could meet the cooling requirement established in 1983, but both contractors met the subsequently revised 1986 baseline cooling requirement. Both exceeded the reliability and maintainability requirements for the generator carts, but one could not meet the reliability or the maintainability requirements for the air conditioner cart. Both contractors met the availability requirement.

Performance under the phase I contracts was a factor considered by the Air Force in making its decision to award the production contract to Teledyne Continental Motors. To reach our February 1989 decision on the bid protests, we examined records to determine whether the Air Force's judgment was reasonable and consistent with stated evaluation criteria and whether there were any violations of procurement statutes and regulations. We concluded there was not a basis for the protests.

Objectives, Scope, and Methodology

During our review we interviewed responsible officials of the Departments of Defense and the Air Force, Washington, D.C., and the Air Force System Command's Aeronautical Systems Division, Wright-Patterson Air Force Base, Dayton, Ohio. We reviewed, but did not verify, the pertinent cost, schedule, and performance information about the program at the Systems Division's program office. We obtained informal comments from responsible agency officials on a draft of this report and incorporated their comments where appropriate. We performed our review from February through April 1989. The results of our work are presented in more detail in appendixes I through IV.

We are sending copies of this report to the House and Senate Committees on Appropriations and on Armed Services; the Secretaries of Defense and the Air Force; the Director, Office of Management and Budget; and other interested parties upon request.

GAO staff members who made major contributions to this report are listed in appendix V.

Sincerely yours,

Harry R. Finley
Director, Air Force Issues

Contents

Cost, Schedule, and Performance Information

After evaluating the proposals received in response to a November 1982 request for proposals to develop a new ground power generator system, the Air Force's Source Selection Authority determined that, based on price and other factors, Ingersoll-Rand Company of Mocksville, North Carolina, and Teledyne Continental Motors of Mobile, Alabama, had the best offers. Accordingly, the Air Force awarded fixed-price full-scale development contracts for phase I to Ingersoll-Rand and Teledyne in December 1983 for $13 million and $12.9 million, respectively. The purpose of each contract was to do research and development, build prototype generator and air conditioner carts, and test them.

Although the cost to the government was a significant evaluation element in determining the awards, technical aspects had greater importance in the selection process. On the basis of modeling results, Air Force officials believed that both Ingersoll-Rand's and Teledyne's approaches indicated a high probability that their projected performances would be achieved.

Ingersoll-Rand proposed a diesel engine that Air Force officials considered an excellent choice based on weight, size, reliability, output power, fuel consumption, and commercial availability. The officials thought that Ingersoll-Rand could meet the fuel consumption requirement. However, they recognized a weakness in the performance of the proposed air conditioner and the risk in developing a compressor. Nevertheless, the officials believed that Ingersoll-Rand's overall experience with design, development, and manufacturing with similar machinery would ensure success and judged the overall technical risk as moderately low.

Air Force officials considered Teledyne's proposed automotive turbine a good choice in terms of power availability, fuel consumption, and engine response time. The officials believed that Teledyne's electrical and compressed air subsystems would exceed requirements and improve fuel consumption. They also believed the air conditioning would exceed required aircraft inlet air conditions. Although the officials did not identify significant weaknesses in the proposal, they recognized areas of risk including the development of the compressor, production of the engine, and development of the control system. They judged the overall technical risk as moderate.

Cost

Some cost increases occurred on the fixed-price contracts because of changes in the scope of the work. Costs increased by $50,731, from $12,900,000 to $12,950,731, for the Teledyne contract and by $379,902,

from $12,989,270 to $13,369,172, for the Ingersoll-Rand contract. Ingersoll-Rand's largest price increase, which totaled $329,500, involved an engineering change for a larger short circuit capability and higher short circuit current levels. (See app. II.)

In addition to these increases, Ingersoll-Rand has filed a $1.7 million claim with the Air Force. The contractor stated that, according to the statement of work, the request for proposals for phase II was to be issued in February 1987. When this did not occur, Ingersoll-Rand said it became necessary to maintain its project team in phase I until the request for proposals was issued.

Schedule

Phase I was originally scheduled to start in November 1983 and end in May 1987. However, it occurred from December 1983 through September 1987—about 4 months longer than initially planned. During this period, delays occurred at various stages. These delays, which are discussed below, were not cumulative because of overlaps in the schedule milestones. (See app. III.) Our discussion focuses on the delays between the original milestones and the dates these milestones were met.

First, according to an Air Force official, the contract award process was delayed because the Air Force changed its source selection procedures from a four-step method to a conventional one, since it believed it had received inadequate initial proposals. Second, the environmental testing was delayed 2 months when a small climatic chamber at Eglin Air Force Base was declared unsafe. Consequently, the contractors had to disconnect the test equipment and computerized data collection systems and install them in another chamber. Third, environmental testing at Eglin was further delayed because of a hurricane alert. As a result, base personnel ordered the base to be shut down, and all test equipment outside of the buildings had to be disconnected and moved inside. After the threat, the contractors had to reinstall and check the equipment. The environmental tests were completed in February 1986. Last, because of concern over the environmental test results, the Air Force delayed the start of further tests. For example, the initial operational test and evaluation began in June 1986, several months later than originally planned. In August 1986 the Air Force also revised the baseline schedules.

Performance

Needed Improvements Over Existing System

In August 1980 the Air Force determined that it needed more efficient and economical means of providing electrical power and cooling air for its tactical fighter aircraft during their maintenance and operational functions. At that time the Air Force considered its ground generator carts coupled with its air conditioner carts extremely fuel inefficient, resulting in high operational and support costs on the flightline. The system used about 45 to 47 gallons of fuel per hour. The scarcity and high cost of fuel were prime considerations in satisfying the Air Force's mobile electric power needs. A 1980 Air Force study identified life-cycle cost savings of about $350 million (in constant fiscal year 1980 dollars) by the year 2000 if newly developed equipment were used only for the F-15 and F-16 aircraft. The study based these savings on what was considered conservative fuel costs of $1 per gallon, adjusted 5 percent annually.

In addition to needing a fuel-efficient system, the Air Force needed air conditioner carts, which could provide sufficient cooling air to the F-15 aircraft in high temperature and high humidity environments. The technical order for the air conditioners in field operations requires that the air conditioners provide a cooling capacity of 98,784 British thermal units per hour in an environment of 100 degrees Fahrenheit with 55 percent relative humidity.

Other deficiencies of the then-existing generators and air conditioners included a noise level at the operator's panel varying from 109 to 113 decibels. According to the Air Force, this level is injurious to the ears without a headset and impairs communication between personnel. The Air Force also considered it necessary to increase the reliability, maintainability, and availability of the equipment. (See app. IV for some of the operating, physical, and readiness requirements established for the equipment and the performance levels achieved by the contractors during phase I.)

Requirement Changes

The phase I technical requirements document, which contained over 100 pages of text and 100 pages of tables, stated many of the Air Force's needs as firm requirements. Some of the requirements established in September 1983 were modified in August 1986. For example, because

the environmental test results caused concern about weight, fuel consumption, and air conditioning quality under the most severe conditions, the Air Force reexamined the technical requirements and lowered some standards. This review resulted in the modified program baseline.

Contractor Performance

In some instances the contractors met or exceeded the technical requirements established for the primary operating characteristics of fuel consumption, noise, and air conditioning and the system readiness parameters of reliability, maintainability, and availability. In other cases, however, the initial requirements were not met. Some of the contractors' technical achievements relating to operating characteristics and system readiness parameters are discussed below.

Fuel Consumption

The original specification called for a consumption of no more than 16 gallons per hour when providing electrical power and air conditioning for the F-15 C/D aircraft. In 1986 this requirement was changed to a goal.

To meet these needs, the contractors developed generator and air conditioner systems that would use various fuels. Tests of these systems showed that Teledyne's prototype used 20.5 gallons per hour and Ingersoll's used 11.2 gallons per hour when providing electrical power and air conditioning for the F-15 C/D aircraft.

Noise Level

The noise level requirement at the operator's panel was no more than 95 decibels, and the requirement at 10 meters from the cart was no more than 83 decibels. Sound test results showed that at the operator's panel Teledyne's system registered 95 decibels, and Ingersoll's registered 94.1 decibels. At 10 meters from the cart, Teledyne's sound level was 82 decibels and Ingersoll's was 78 decibels.

Air Conditioning

A critical performance parameter is to provide sufficient conditioned air for servicing the F-15 aircraft. Early in the full-scale development, the Air Force established the cooling requirements to provide for anticipated "growth" in F-15 requirements in the most severe worldwide environment. This climatic condition requires the ground power generator system to provide a cooling equivalent of approximately 206,000 British thermal units per hour. The number of British thermal units

required is dependent on the external environment in which the air conditioner must operate and the desired cooling effect (the combined effect of humidity, temperature, and airflow) inside the aircraft. Neither contractor could meet this requirement. Teledyne's system could produce approximately 182,000 British thermal units per hour and Ingersoll's system approximately 161,000 units per hour.

Because the Air Force believed the requirement was overstated, in August 1986 it lessened the environmental conditions requirement in which the air conditioner must perform. As a result, the cooling equivalent requirement was reduced to 151,000 British thermal units per hour to reflect the next step down in environmental conditions. Consequently, both contractors exceeded the lowered cooling equivalent requirement.

Reliability, Maintainability, and Availability

The reliability requirement for mean time between maintenance at maturity for the generator cart was 70 hours, and the requirement for the air conditioner cart was 135 hours. Both contractors met the reliability requirement for the generator cart—Ingersoll's mean time between maintenance was 151 hours, and Teledyne's was 115 hours. Teledyne met the reliability requirement for the air conditioner cart—its mean time between maintenance was 146 hours, and Ingersoll's was 119 hours.

The mean time between preventive maintenance parameter was 200 hours or 6 months, whichever occurred first. Both contractors exceeded the preventive maintenance requirement hours.

The maintainability requirement was 4 hours mean time to repair a failure in either cart. It took about 1 hour to repair Ingersoll's generator cart and almost 5 hours to repair its air conditioner cart. Teledyne's generator cart took 3 hours to be repaired, and its air conditioner cart took 2.4 hours for repair. Hence, both contractors' generator carts met the maintainability requirement, but only Teledyne's air conditioner cart met the requirement.

The availability requirement of 95 percent at maturity was exceeded by both contractors. Ingersoll's availability for both of its carts ranged from 99.5 to 99.8 percent, and Teledyne's was 98.5 percent for its generator cart and 99.8 percent for its air conditioner cart.

Cost of Research and Development Contracts for a Ground Power Generator System

Date	Item	Cost	
		Teledyne	Ingersoll-Rand
December 1983	Basic contract	$12,900,000	$12,989,270
December 1984	Specification change	[a]	9,799
February 1985	Engineering change	[a]	31,456
November 1985	Test equipment move	70,129	58,315
January 1986	Specification deletion	−12,533	[a]
January 1986	Engineering change	[a]	329,500
February 1986	Engineering change	[a]	5,260
April 1986	Statement of work changes	46,520	23,765
February 1987	Testing change	[a]	−9,750
May 1987	Testing change	[a]	−68,443
September 1987	Testing change	−53,385	[a]
Total		**$12,950,731**	**$13,369,172**

Note: In January 1989 Ingersoll-Rand made a claim for recovering $1.7 million under phase I. The company stated it maintained its project team by stretching out phase I until the request for proposals for phase II was issued.

[a]No changes occurred.

Schedule for Research and Development of the Ground Power Generator System

Milestones	Baseline projections		Month performed
	September 1983	August 1986	
Award of research and development contracts	November 1983	December 1983	December 1983
Initiate environmental tests	June 1985	August 1985	August 1985
Complete environmental tests	October 1985	February 1986	February 1986
Initiate initial operational test and evaluation	November 1985	June 1986	June 1986
Initiate design life testing/Department of Defense qualifications	December 1985	April 1986	June 1986
Complete initial operational test and evaluation	February 1987	August 1987	September 1987
Complete design life testing/Department of Defense qualifications	May 1987	August 1987	August 1987

Note: The above schedule pertains to both Teledyne Continental Motors and Ingersoll-Rand Company.

Technical Requirements and Contractor Development of a Ground Power Generator System

Technical requirements	Baseline requirements		Research and development actual performance	
	Sep. 1983	Aug. 1986	Teledyne	Ingersoll-Rand
Operating characteristics				
Electrical power				
Alternating current — 115/200 volts, 400 Hertz, 3 phases, 30 kilowatts	Same	Same	Same	Same
Direct current — 24 and 28 volts (200 and 10 amperes, respectively)	Same	Same	10 amperes	10 amperes
Compressed air				
pounds per minute corrected airflow	50.0	50.0	50.2	50.25
at total pressure ratio	3.65	3.65	3.66	3.58
pounds per minute corrected airflow	39.0	39.0	40.4	39.82
at total pressure ratio	3.69	3.69	3.73	3.61
Air conditioning				
Output for conditioned air				
Minimum output pounds per minute	92	92	98	105
Maximum degrees Fahrenheit	50	50	75	76
Minimum pounds per square inch	3	3	3.5	5
Maximum relative humidity, percent	80	80	32	57
Maximum external operating environment				
Degrees Fahrenheit	95	98	97	98
Relative humidity, percent	80	50	60	50
Cooling equivalent				
British thermal units per hour	206,000	151,000	182,000	161,000
Fuel consumption				
Gallons per hour (baseline load at environmental testing)	16	16 (goal)	20.5	11.2
Multi-fuel capability				
Jet petroleum	4,5,8	4,5,8	All fuels	All fuels
Diesel fuel	1,2,A	1,2,A	All fuels	All fuels
Maximum noise level, decibels				
at operator's panel	95	95	95	94.1
at 10 meters from cart	83	83	82	78
Physical characteristics				
Generator cart				
Maximum weight, pounds	5,800	5,820 (goal)	6,600	5,900
Maximum length, inches	135	135	134.2	135
Maximum width, inches	75	75	67.6	67
Maximum height, inches	78	78	77.1	72
Air conditioner cart				
Maximum weight, pounds	2,500	2,500 (goal)	2,660	1,840
Maximum length, inches	85	85	85.5	85
Maximum width, inches	75	75	70.5	65.1
Maximum height, inches	78	78	70.3	66.5

(continued)

Technical requirements	Baseline requirements		Research and development actual performance	
	Sep. 1983	Aug. 1986	Teledyne	Ingersoll-Rand
Operating concept				
Operate on flightline and Tab Vee shelter	Same	Same	Same	Same
Manual positioning, number of people				
Generator cart	2	2	2	2
Air conditioner cart	1	1	1	1
Rapid set up/connect or dismantle, minutes	Less than 5	Less than 5	1.53	1.82
Extreme worldwide temperature, degrees Fahrenheit				
Low	−50	−50	−50	−50
High	128	128	128	128
All mode transportability — two carts	Same	Same	All modes	All modes
System readiness parameters				
Full mission capable rate (at maturity), percent	95	95		
Ground power generator			98.5	99.8
Air conditioner			99.8	99.5
Mean time between corrective maintenance (at maturity), hours				
Generator cart	70	70	115	151
Air conditioner cart	135	135	146	119
Mean time between maintenance (preventive), hours	200 (or 6 mo)	200 (or 6 mo)		
Ground power generator			221	252
Air conditioner			332	217
Mean time to repair, hours				
Ground power generator	4	4	3.17	.96
Air conditioner	4	4	2.4	4.94
Mean time to perform preventive maintenance, hours				
Ground power generator	4	4	.9	2.38
Air conditioner	2	2	.19	.76
Fault isolation (diagnostic capability), percent				
To one shop replaceable unit	90	90	100	100
To two shop replaceable units	95	99	100	100
To three shop replaceable units	100	100	100	100
Manual propulsion, pounds				
Force to move generator cart	[a]	120	110 (avg.)	89 (avg.)
Force to move air conditioner cart	[a]	50	35 (avg.)	37 (avg.)

Source: Aeronautical Systems Division, Air Force Systems Command

[a]Not specified

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