VECTOR CARDIOGRAPH EXPERIMENT IN SPACE SHUTTLE

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ABSTRACT

The Vector cardiography is the 3 dimensional study of Electrocardiographic responses of the human heart. A Vector cardiograph (VCG) instrument was designed and developed to monitor the Cardiographic responses of the Indian payload specialist under zero G conditions in the US Space Shuttle during the scheduled INSAT-lC launch. Accordingly the proposal made by Department of Space for using the vector cardiograph measurement in the Space Shuttle was accepted. A VCG unit was developed under the joint collaboration of HAL, Hyderabad and ISAC-ISRO. This paper brifly describes the design aspects of the VCG instrument, the qulification tests conducted on the same for space application and the final test results obtained during the process. Basically the instrument was built around a Hybrid Instrumentation amplifier and other interfaces for recording the signal into an audio taperecorder.

1. INTRODUCTION

The vector cardiograph experiment (VCG) was proposed to be carriedout onboard US Space shuttle during the scheduled launch of the Indian National Satellite INSAT-lC. It was an upgraded version of a similar experiment which was carried out on board SALYUT space station by the Indian cosmonaut. One of the significant physiological changes one can observe under the ‘zero G’ conditions prevailing in the oribital flight is on the haemodynamics of the cardiovascular system and the corresponding marked changes in the electrical activates of the heart. In the early space flights conventional scalar electrocardiogram (ECG) was routinely recorded and the changes in the intervals between various ECG components were studied. Preflight and postflight

recordings of several of the APOLLOcrew members indicated ECG amplitude differences. Similar ECG findings were also reported from soviet cosmonauts. Apart from those related to the heart, the changes were mainly those of the P & QRS vector magnitudes and orientiation shifts. The vector cardiograph (VCG) experiment described in this paper was designed mainly to monitor the electro cardiographic responses of the human heart of the Indian payload specialist onboard space shuttle, picked up through orthogonal vector leads, which were amplified and recorded in a tape recorder for data logging. The main objective of this life science experiments of the shuttle mission was to study the effect of YOGA exercises on the human heart under zero G conditions.

2. REENGINEERING ASPECTS

The VCG system which was used for the SALYUT Mission consists of a three channel amplifier, a power supply unit (DC to DC converter) and a 4 channel FM tape recorder for recording the VCG signals. However, the following reengineering was carried out for the shuttle Mission.

1. The power supply unit housing the DC to DC converter was completely eliminated and instead the complete electronics was made to operate with campact battery packs housing the alkaline dry cells.
2. The electronics packages were made compatible to meet the shuttle retirements as per the NASA interface document ICD-2-lM001. The VCG amplifiers were designed with hybrid microcircuits.
3. The bulky FM recorder was replaced by a NASA approved SONY Walkman professional stereo cassette recorder.
4. Additional voltage controlled oscillators along with signal mixer package was introduced for providing necessary interface between the VCG amplifier and the SONY taperecorder.
5. A 100% redundancy was provided for the complete system and the complete block schematic of the VCG system is shown in fig.1

3. SYSTEM SPECIFICATIONS

3.1. VCG AMPLIFIER

(1) Gain of the amplifier X,Y,& Z channels	:1000 +/- 10%
(2) Frequency response of the X,Y,& Z ch.	:0.5 Hz to 150 Hz
(3) I/P impedance of each channel	:10M ohms
(4) CMRR of each channel	:Better than 70 dB
(5) Output impedance	:100 Ohms
(6) Calibration signal	:1 mV +/-20%
(7) Supply voltages	:+/- 12 volts DC

3.2. VOLTAGE CONTROL OSCILLATOR UNIT

(1) Frequencies.	: (1) 1.7 KHz +/- 7.5%
	: (2) 3.9 KHz +/- 7.5%
	: (3)7.35 KHz +/- 7.5%
(2) Modulating signal	: DC to 150 Hz
(3) Input impedance	: 10 K ohms
(4) Linearity of the VC	: Better than 0.1%
(5) Output impedance	: Less than or equal to 100 ohms
(6) Supply voltage	: +/- 9 volts DC
(7) Power dispation	: 350 mW

4. SYSTEM DESCRIPTION

Signals from the payload spcialists body at different locations are picked up by 8 sensors and are connected to the VCG amplifier unit through a resistor network . This resistor network resolves these 8 signals into three differential outputs using the well established Dr. Franks principle. These X,Y&Z Signals are amplified inside the VCG unit by a factor of about 1000. Each of these three outputs will modulate a separate IRIG subcarrier selected for this purpose. Additionaly, these X,Y,Z signals are further amplified and rectified to drive the Bargraph display module fixed on the VCG unit . The Bar graph display enables the payload specialist to not only ensure the correct operation of the VCG unit but also to correctly fix the sensors on to his body during the flight.

The freqency modulator used here is basically a voltage controlled oscillator. It was designed around a standard astable multi, and this type of VCO has a proven flight history. The square wave outputs of the VCO’s were shaped by the active Bandpass filters. The three frequency modulated signals were then mixed in a passive mixer and the composite signal was recorded in the SONY Walkman stereo cassette recorder. Two separate mixers were used for

providing redundancy and these two mixer outputs were recorded on the two channels of the stereo recorder having a bandwidth up to 15KHz. The quality of the recording during the mission could be ensured by listening to the audio tones of the VCG signals using a headphone.

5. DEVELOPMENT PLAN

As the VCG units were supposed to be mounted in a tray using velcros and the tray being pushed into the middeck locker of the Space shuttle, it was essential to have an integrated Quality Assurance plan covering all the aspects of the material control, inspection and quality control along with the Test and Evaluation. A quality assurance plan was drawn to ensure utmost reliability and safety of the instrument for conducting the VCG experiment in space shuttle. The specifications were derived from ICD document of NASA for Space Shuttle.

The Flight model units of the VCG intended to be flown in the Space Shuttle, were designed and fabricated using only MIL approved components and these units underwent the flight acceptance tests. One of these models which was despatched to NASA successfully underwent the outgassing and EMI tests at LOSALMOS. The results of the outgassing tests conducted on the Flight version of the VCG are indicated in Appendix-I.

The Flight version of the VCG system was subjected to the following qualification tests as per the Quality Assurance plan and the system’s performance was flawless throughout.

1. Initial Bench Test
2. EMI/EMC Test
3. Operational Hot and Cold Soak Test
4. Random Vibration Test
5. Temperature burn in for 168 hours
6. Final Bench Test and delivery to the Project.

6. TESTING AND TRAINING

The VCG amplifiers were checked both in the calibration mode as well as in the Normal mode (VCG mode). In the calibration mode, the calibration signals of 1 volt and lHz were recorded in the recorder. In the Normal mode the cardiographic responses of the payload specialist served as the inputs to the amplifier which were recorded. For checking the accuracy of the data recorded, the recorded

data was played back. This data was given to a set of Bandpass Filters and Frequency Discriminators tuned to the 3 VCO frequencies which was also developed inhouse. The corresponding outputs of the Frequency Discriminators were compared on an oscilloscope. The VCG units were extensively used in the training of the Indian payload specialists who were selected for this mission at the Institute of Aviation Medicine, Bangalore,lndia.

7. CONCLUSION

The VCG system for the Life Science Experiment in the space shuttle was developed by ISRO-HAL jointly, and was fully qualified to shuttle environments. Due to the unfortunate disaster of space shuttle Challenger in 1986 the Indian Payload Specialist Flight Mission (IPSFM) had to be prematurely terminated. Nevertheless, this VCG system developed for that mission has given sufficient experience in the design and qualification of electronics hardware for shuttle mid-deck system.

8. ACKNOWLEDGEMENT

The authors wish to express their sincere gratitude to the Mission Director, IPSFM for providing an opportunity to develop this system and Director, ISAC for providing all the necessary guidance and technical support in delivering the hardware. The authors would like to express their gratitude also to all the personnel associated with this experiment at Hindustan Aeronautics Ltd, Hyderabad, at Institute of Aviation Medicine (IAM), Bangalore and at ISRO Satellite centre, Bangalore for all their valuable technical support.

APPENDIX-I
NASA HANDBOOK 8060.1B
TEST 16 : DETERMINATION OF OFFGASSED PRODUCTS FROM ASSEMBLED ARTICLES

TEST ARTICLE : IPSE Hardware (Indian Payload Specialist Experiment)

TEST ARTICLE PREPARATION :
The test article consisted of a subcarrier oscillator, 12V battery pack, 9V battery pack, vectorcardiograph, and cables. The yellow and red plastic covers, Post It Notes, and tape were removed and were not included for testing.

TEST CONDITIONS:

Test Temparature : 120± 5 Deg F	Test Duration : 72 hours
Test Pressure : 11.8 to 12.0 psia	Sample Weight : 4192 grams
Test Atmosphere : 25.9% Oxygen and 74.1% Nitrogen	Chamber Free Volume : 16.1 liters

TEST RESULTS, OBSERVATIONS AND COMMENTS :

OFFGASSED PRODUCTS

Component	NASA National Chemical code	Toxic Limit (micrograms per gram)	Quantity (micrograms per gram)
Carbon Monoxide	161000	40.90	0.039
Acetaldehyde	020300	77.10	0.007
Methyl alcohol	014800	74.90	0.070
Butene	097600	7.15	0.001
Fluorotrimethyl silane	168550	0.13	0.001
Ethyl alcohol	013600	134.00	0.003
Acrolein	020900	0.16	0.001
Acetone	110500	1,018.00	0.035
Isopropyl alcohol	016400	140.00	0.17
Dichloromethane	064200	124.00	0.001
t-Butyl alcohol	012400	173.00	0.002
n-Propyl alcohol	016000	140.00	0.008
Trimethyl silanol	168500	2.58	0.020
Ethyl acetate	042400	257.00	0.002
1,2-Dichloroethane	062700	61.76	0.006
n-Butyl alcohol	011600	173.00	0.007
Pentanal	024000	151.00	0.001
Trichloroethylene	065700	0.77	0.002
2-Ethoxyethanol	013550	105.61	0.001
Methyl isobutyl ketone	116000	117.00	0.001
Toluene	035200	108.00	0.017
C6 Aldehyde	026000	3.43	0.003
n-Butyl acetate	041200	271.00	0.003
Hexamethyl cyclotrisiloxane	164500	324.00	0.051
C7 Ether	057500	0.13	0.014
Xylene	039100	124.00	0.001
2-Ethoxy ethyl acetate	042000	232.00	0.008
Octamethyl cyclotetrasiloxane	165100	217.39	0.009
Decamethyl cyclopentasiloxane	163000	0.13	0.001

NASA QUALITY ASSURANCE
DATE : FEB 23.87

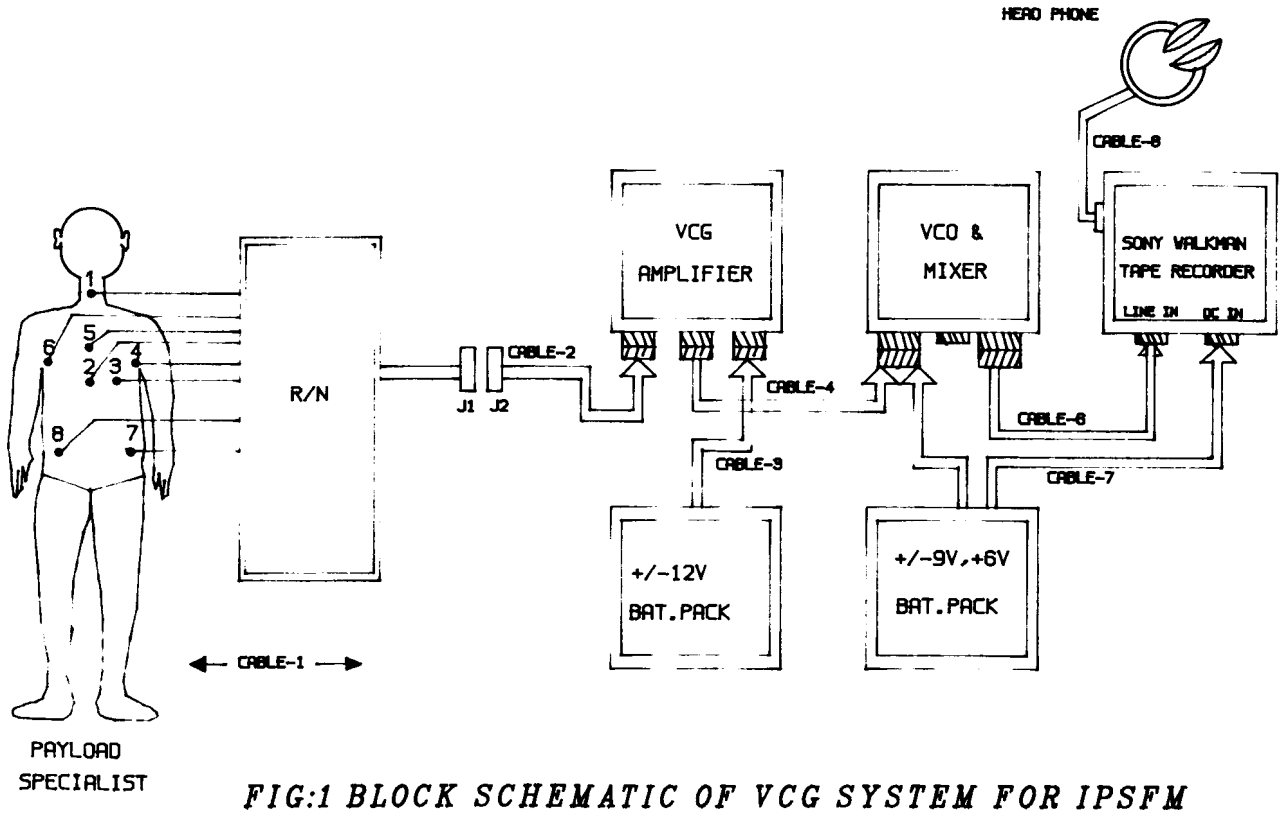
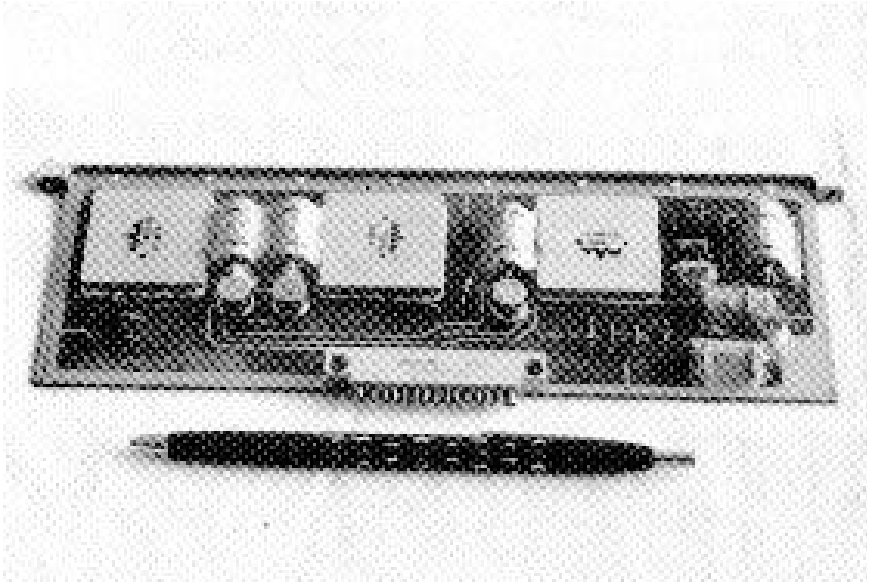
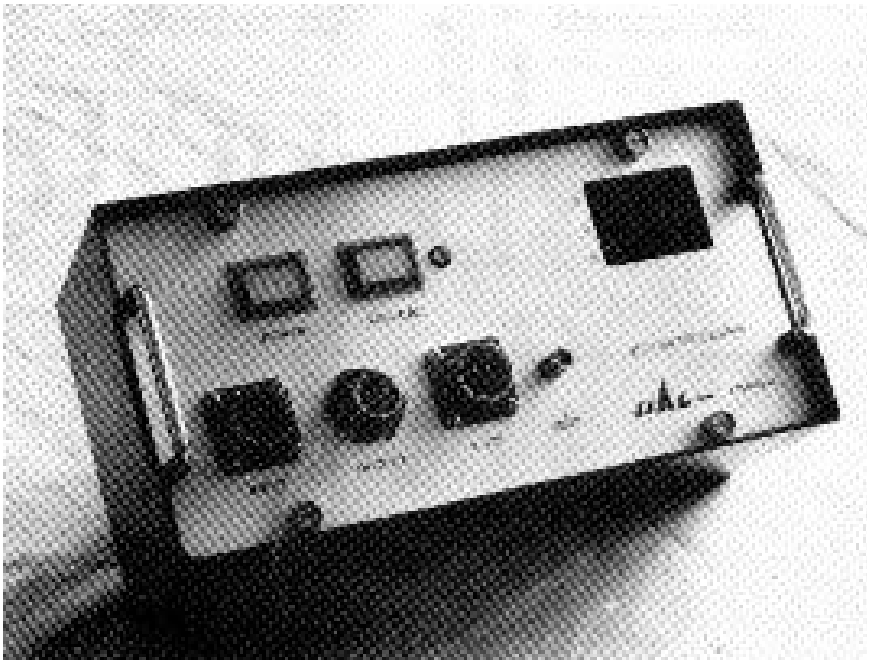


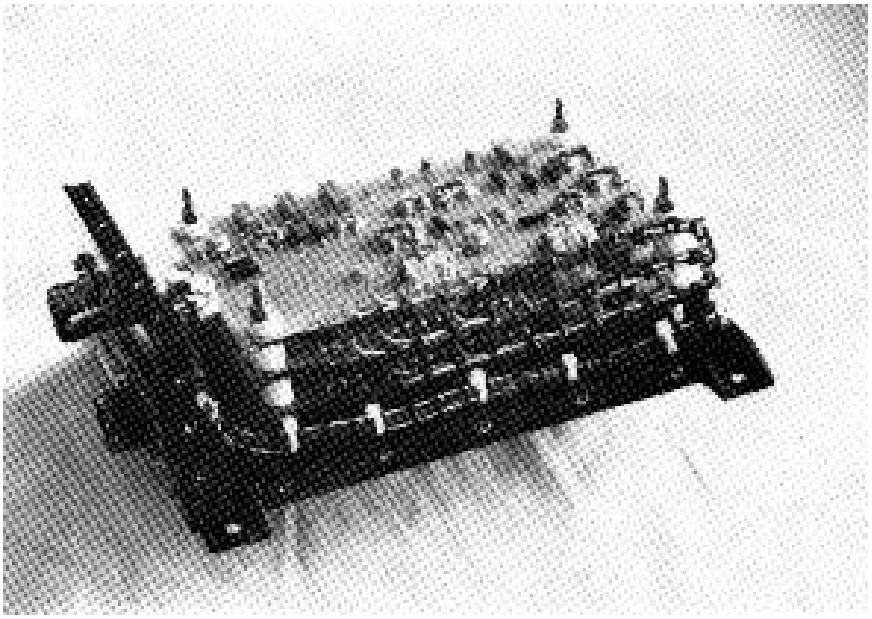
FIG:1 BLOCK SCHEMATIC OF VCG SYSTEM FOR IPSFM



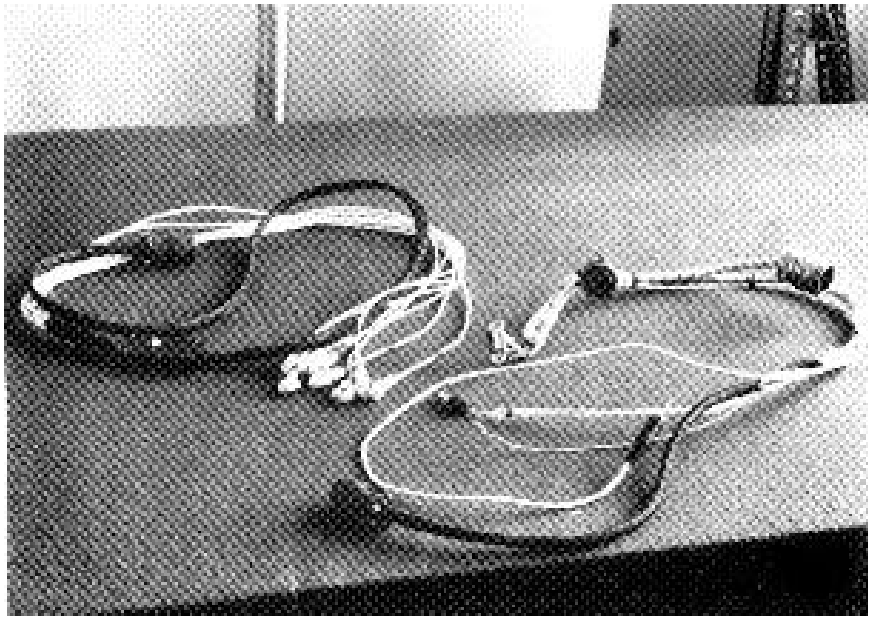
3 CHANNEL VCG AMPLIFIER

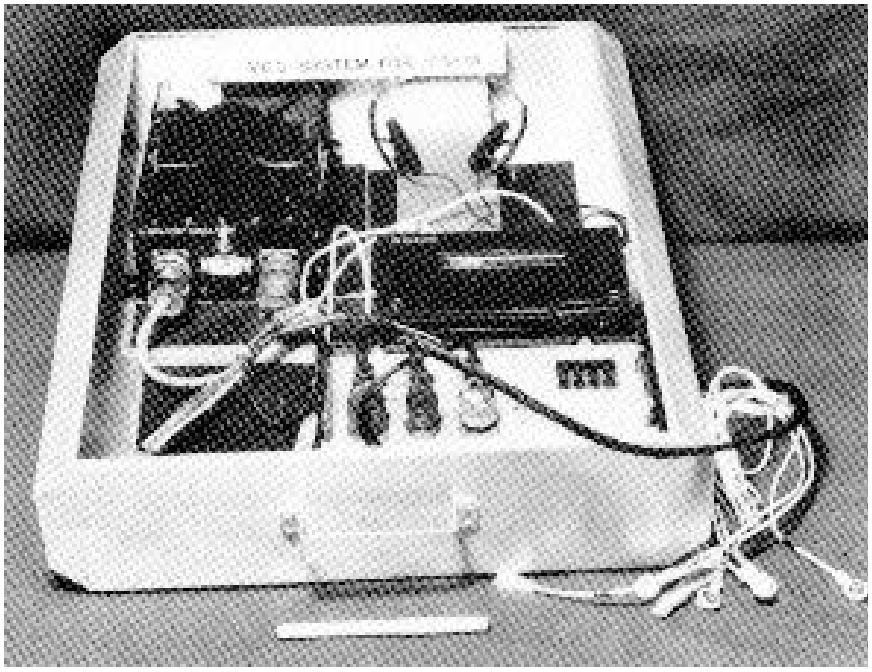


SUBCARRIER OSCILLATOR PACKAGE

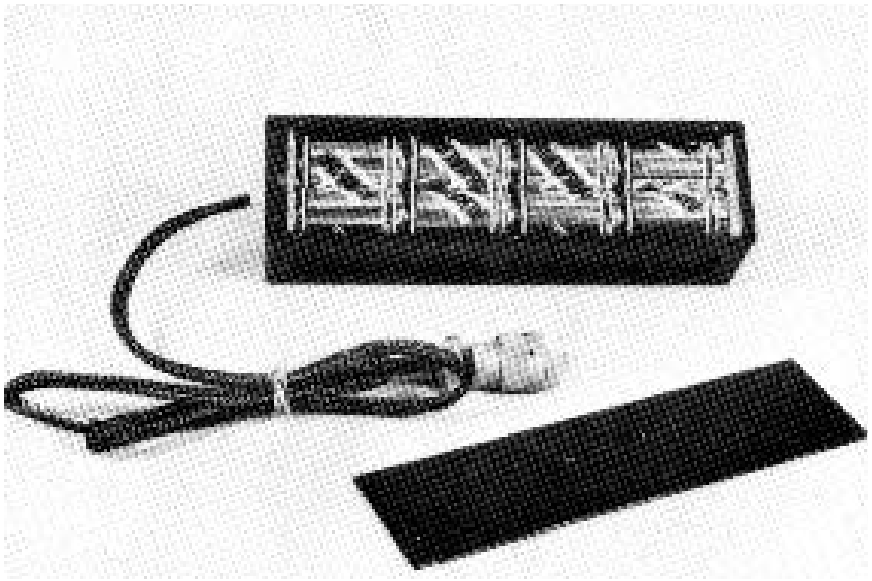


TAPE RECORDER FOR VCG





VCG IN SMALL STOWAGE TRAY



BATTERY PACK FOR VCG