



Aerospace Medicine  
and Biology  
A Continuing  
Bibliography  
with Indexes

NASA SP-7011 (344)  
January 1991

(NASA-SP-7011(344)) AEROSPACE MEDICINE AND  
BIOLOGY: A CONTINUING BIBLIOGRAPHY WITH  
INDEXES (SUPPLEMENT 344) (NASA) 92 p

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National Aeronautics and  
Space Administration

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## ACCESSION NUMBER RANGES

Accession numbers cited in this Supplement fall within the following ranges.

STAR (N-10000 Series) N90-28489 — N90-30170

IAA (A-10000 Series) A90-49870 — A90-53109

# AEROSPACE MEDICINE AND BIOLOGY

A CONTINUING BIBLIOGRAPHY  
WITH INDEXES

(Supplement 344)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in December 1990 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA)*.



National Aeronautics and Space Administration  
Office of Management  
Scientific and Technical Information Division  
Washington, DC 1991

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# INTRODUCTION

This Supplement to *Aerospace Medicine and Biology* lists 258 reports, articles and other documents announced during December 1990 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA)*. The first issue of the bibliography was published in July 1964.

In its subject coverage, *Aerospace Medicine and Biology* concentrates on the biological, physiological, psychological, and environmental effects to which man is subjected during and following simulated or actual flight in the Earth's atmosphere or in interplanetary space. References describing similar effects on biological organisms of lower order are also included. Such related topics as sanitary problems, pharmacology, toxicology, safety and survival, life support systems, exobiology, and personnel factors receive appropriate attention. In general, emphasis is placed on applied research, but references to fundamental studies and theoretical principles related to experimental development also qualify for inclusion.

Each entry in the bibliography consists of a bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by *STAR* categories 51 through 55, the Life Sciences division. The citations, and abstracts when available, are reproduced exactly as they appeared originally in *IAA* or *STAR*, including the original accession numbers from the respective announcement journals. The *IAA* items will precede the *STAR* items within each category.

Seven indexes — subject, personal author, corporate source, foreign technology, contract, report number, and accession number — are included.

An annual index will be prepared at the end of the calendar year covering all documents listed in the 1990 Supplements.

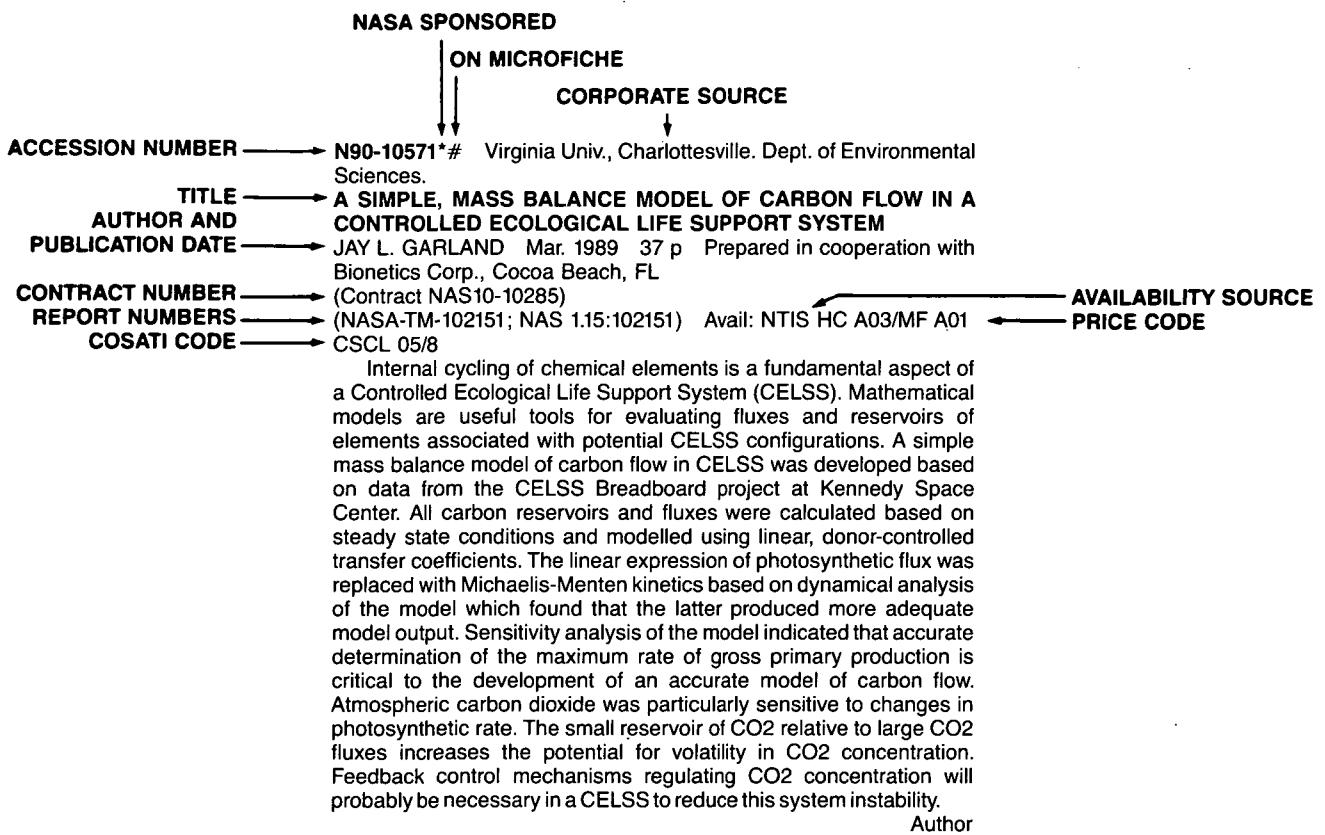
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Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

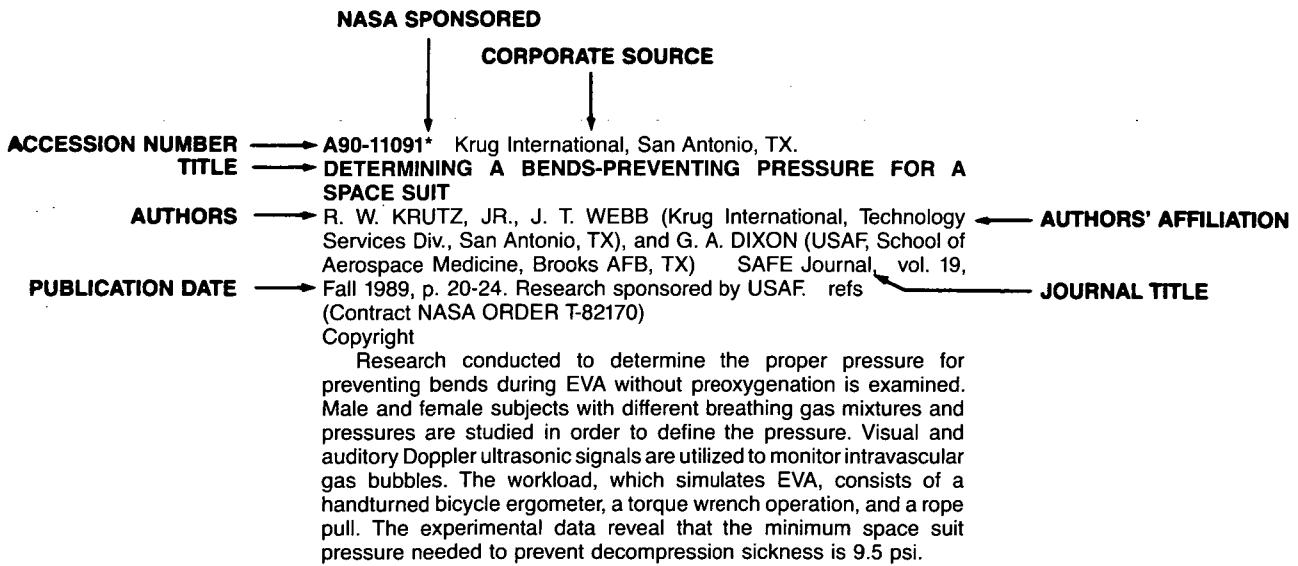
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# TYPICAL REPORT CITATION AND ABSTRACT



# TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



# AEROSPACE MEDICINE AND BIOLOGY

*A Continuing Bibliography (Suppl. 344)*

JANUARY 1991

51

## LIFE SCIENCES (GENERAL)

A90-49938

### A SECOND CLASS OF SYNTHETASE STRUCTURE REVEALED BY X-RAY ANALYSIS OF ESCHERICHIA COLI SERYL-TRNA SYNTHETASE AT 2.5 Å

STEPHEN CUSACK, CARMEN BERTHET-COLOMINAS, MICHAEL HARTLEIN, NICOLAS NASSAR, and REUBEN LEBERMAN (European Molecular Biology Laboratory, Grenoble, France) *Nature* (ISSN 0028-0836), vol. 347, Sept. 20, 1990, p. 249-255. refs

Copyright

A90-50740

### EMOTIONAL STATE DYNAMICS IN THE WAKEFULNESS-SLEEP CYCLE [DINAMIKA EMOTSIONAL'NOGO SOSTOIANIIA V TSIKLE BODRSTVOVANIE-SON]

M. G. KORIDZE and M. G. KAVKASIDZE (AN GSSR, Institut Fiziologii, Tbilisi, Georgian SSR) Akademii Nauk Gruzinskoi SSR, Soobshcheniya (ISSN 0132-1447), vol. 137, Feb. 1990, p. 389-392. In Russian. refs

Copyright

A series of experiments was carried out on cats with brain-implanted electrodes to investigate the dynamics of emotional states in the wakefulness-sleep cycle in terms of the relationship between the hippocampal theta rhythm, REMs, and cardiac rhythm. It is suggested that the regulation of motivation processes during paradoxical sleep is due to the brain structures that trigger the emotional reactions in wakefulness.

V.L.

A90-50788

### THE NATURE OF HYPERMETABOLISM AND TACHYCARDIA DURING ADAPTATION TO COLD AND EXPERIMENTAL HYPERTHYROIDISM [PRIRODA GIPERMETABOLIZMA I TAKHIKARDII PRI ADAPTATSII K KHOLODU I EKSPERIMENTAL'NOM GIPERTIREOZE]

V. I. SOBOLEV and N. T. LAPENKO (Donetskii Gosudarstvennyi Universitet, Donetsk, Ukrainian SSR) *Fiziologicheskii Zhurnal* (Kiev) (ISSN 0201-8489), vol. 36, July-Aug. 1990, p. 22-28. In Russian. refs

Copyright

The contributions of humoral and nonhumoral components to the development of hypermetabolism and tachycardia during adaptation to cold (AC) and experimental hyperthyroidism (HT) are examined in rats subjected to the cross-circulation operation. The animals were divided into control (C), AC, and HT rats, and the heart rate, the rectal temperature, and the consumption of oxygen were measured before and during the cross circulation experiment in five pairs of rats: C-C, C-HT, HT-HT, C-AC, and AC-AC. It is shown that, under experimental hyperthyroidism, the contribution of humoral factors to the origin of hypermetabolism equaled 22 percent (with the remaining 78 percent being nonhumoral), while the humoral contribution to the genesis of

tachycardia was 44 percent. In rats adapted to cold, the increases of the basal metabolism and tachycardia due to humoral agents equaled 77 percent and 65 percent, respectively. I.S.

A90-50790

### PROTECTIVE EFFECT OF ENERGY SUBSTRATES, VITAMINS, COENZYMES, AND THEIR COMPLEXES ON AN ORGANISM AFFECTED BY CLOSED-SPACE FACTORS [ZASHCHITNYI EFFEKT ENERGETICHESKIH SUBSTRATOV, VITAMINOV, KOFERMENTOV I IKH KOMPLEKSOV PRI DEISTVII NA ORGANIZM FAKTOROV ZAMKNUTOGO PROSTRANSTVA]

I. I. ABU ASALI, V. A. ROZANOV, and A. IA. ROZANOV (Odesskii Gosudarstvennyi Universitet, Odessa, Ukrainian SSR) *Fiziologicheskii Zhurnal* (Kiev) (ISSN 0201-8489), vol. 36, July-Aug. 1990, p. 32-37. In Russian. refs

Copyright

The effect of oxidation substrates, vitamins, and vitamin-coenzyme complexes on the survival time of mice maintained under hypoxic conditions of crowded and hermetically sealed space (allowing from 125 to 688 cu cm/mouse) was investigated. The survival time was measured in mice pretreated with L-aspartate; L-asparagine; L-glutamate; GABA; alpha-ketoglutarate; pyruvate; succinate; pyridoxal 5-prime-phosphate; a complex containing pyridoxal 5-prime-phosphate, pentapyruvate, and a lipoate; and a vitamin-coenzyme complex in combination with an oxidation substrate. GABA, aspartate, and glutamate exhibited the highest protective effect.

I.S.

A90-50790

### THE EFFECT OF HYPOXIA ON THE ACTIVITY OF GLUCOSE-6-PHOSPHATE DEHYDROGENASE IN RAT ERYTHROCYTES [VLIJANIE GIPOKSII NA AKTIVNOST' GLIUKOZO-6-FOSFATDEGIDROGENAZY V ERITROTSITAKH KRYS]

V. P. DUDAREV and L. N. STROKACH (AN USSR, Institut Fiziologii, Kiev, Ukrainian SSR) *Fiziologicheskii Zhurnal* (Kiev) (ISSN 0201-8489), vol. 36, July-Aug. 1990, p. 37-42. In Russian. refs

Copyright

The protective effect of glucose-6-phosphate dehydrogenase (G-6-P dehydrogenase) under altitude hypoxia was studied in rats kept at various periods at an altitude of 2100 m above sea level or in a hypobaric chamber at 7500 m or 9000 m simulated altitude. Results of biochemical blood analyses showed that the adaptation of rats to high altitude is accompanied by an increase in the G-6-P dehydrogenase activity. This enzyme was also found to increase in rats with nitrite-induced methemoglobinemia and in those with phenylhydrazine-induced anemia as well as in rats injected with ionol.

I.S.

A90-51392

### ONSET OF BEHAVIORAL EFFECTS IN MICE EXPOSED TO 10 GY CO-60 RADIATION

DONNA M. MAIER and MICHAEL R. LANDAUER (U.S. Armed Forces Radiobiology Research Institute, Bethesda, MD) *Aviation, Space, and Environmental Medicine* (ISSN 0095-6562), vol. 61, Oct. 1990, p. 893-898. refs

Copyright

The effects of 10 Gray (Gy) Co-60 radiation on social behavior, locomotor activity, and body weight were assessed in individually

## 51 LIFE SCIENCES (GENERAL)

housed male Swiss-Webster mice. In experiment 1, aggressive behavior was evaluated prior to irradiation and for 7 d postirradiation by placing an untreated intruder in the irradiated or sham-irradiated resident's home cage for 5 min. Offensive aggressive behavior was not affected significantly by radiation until day 7 postirradiation, when attack latency increased, the frequency and duration of fighting decreased, and the frequency of bites, lunges, and chases decreased. Untreated intruder mice paired with irradiated resident mice showed a decrease in the duration of defensive upright postures and a decrease in the frequency of defensive upright postures, squeaks, and escapes on day 7 postirradiation. In experiment 2, locomotor activity and body weight were monitored for 7 d postirradiation. Body weight was decreased in irradiated mice beginning 4 d postirradiation. Locomotor activity was suppressed in irradiated animals 90 min after irradiation and remained depressed throughout the 7-d testing period. Author

A90-51664

### EFFECTS OF ANGULAR SPEED IN RESPONSES OF PARAMECIUM TETRAURELIA TO HYPERGRAVITY

H. PLANEL, G. RICHOILLEY, C. CARATERO, R. TIXADOR, C. CARATERO (Toulouse III, Universite, Toulouse, France) et al. Microgravity Science and Technology (ISSN 0938-0108), vol. 3, Sept. 1990, p. 107-109. Research supported by CNES.

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The paper shows the results of investigations carried out in a single-cell organism (Paramecium tetraurelia) exposed to different gravitational levels. Hypergravity resulted in a decrease in cell growth rate. The responses depend on g level and angular speed of the centrifuge; furthermore they depend also on small short fluctuations in g levels (Delta-g) due to the swimming of the cells inside the culture tubes. Delta-g depends on angular speed and size of the holding device. The inhibitory effect of hypergravity, for the same angular speed, increases with respect of the diameter of the culture tubes. Author

A90-51665

### RESPONSES OF THE PHOTOSYNTHETIC FLAGELLATE, EUGLENA GRACILIS, TO MICROGRAVITY

D. P. HAEDER, K. VOGEL, and J. SCHAEFER (Erlangen-Nuernberg, Universitaet, Erlangen, Federal Republic of Germany) Microgravity Science and Technology (ISSN 0938-0108), vol. 3, Sept. 1990, p. 110-116. Research supported by BMFT. refs

Copyright

Motility and orientation have been studied in the unicellular photosynthetic flagellate, Euglena gracilis, using real time image analysis capable of tracking up to 200 cells simultaneously before, during and after a sounding rocket (Texus) experiment. The cells orient negative gravitactically under 1 g conditions and the degree of orientation increases with time when kept in a closed system. Under micro-g conditions the cells orient randomly and display no cooperativity between the individuals. Under 1 g conditions the velocity, which has been determined simultaneously to the orientation vectors, depends on the direction of swimming with respect to the gravity vector. Under micro-g conditions the cells swim significantly faster. After retrieval of the rocket the cells returned to normal gravitaxis and motility as observed before the space flight. Author

A90-52401

### BLOOD FLOW AND OXYGEN TENSION IN THE BRAIN OF A CENTRAL-ASIAN TORTOISE UNDER HYPERTERMIA AND HYPOTHERMIA [KROVOTOK I NAPRIAZHENIE KISLORODA V MOZGE SREDNEAZIATSKOI CHEREPAKHI PRI GIPER- I GIPOTERMII]

S. B. ISABEKKOVA and N. M. KARIAGINA (AN KSSR, Institut Fiziologii, Alma-Ata, Kazakh SSR) Fiziologicheskii Zhurnal SSSR (ISSN 0015-329X), vol. 76, June 1990, p. 754-759. In Russian. refs

Copyright

The dynamics of cerebral blood flow and of oxygen tension (PO<sub>2</sub>) in Central-Asian tortoises (*Agrionemys horsfieldi*) were

investigated under conditions of hyperthermia and hypothermia. The total and the local blood flow and the PO<sub>2</sub> were found to depend on the body temperature of the animal. Correlative measurements of changes in the blood flow, PO<sub>2</sub>, blood pH, and hematocrit suggest that the blood flow in reptiles is regulated by metabolic factors. I.S.

A90-52402

### COMPARATIVE CHARACTERISTICS OF ARTERIAL

### PRESSURE CHANGES IN HYPERTENSIVE AND

### NORMOTENSIVE RATS UNDER THERMAL STRESS

### [SRAVNITEL'NAIA KHARAKTERISTIKA IZMENENII

### ARTERIAL'NOGO DAVLENIIA U GIPERTENZIVNYKH I

### NORMOTENZIVNYKH KRYS PRI TEPOLOVOM VOZDEISTVII]

V. A. TASHLEV (AN SSSR, Institut Fiziologii, Leningrad, USSR) and D. P. DVORETSKII (AN TSSR, Institut Fiziologii i Ekspertimental'noi Patologii Aridnoi Zony, Ashkhabad, Turkmen SSR) Fiziologicheskii Zhurnal SSSR (ISSN 0015-329X), vol. 76, June 1990, p. 764-769. In Russian. refs

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A90-52403

### THE IMPULSE ACTIVITY OF THERMOREGULATORY-CENTER

### NEURONS IN A THERMONEUTRAL ENVIRONMENT

### [IMPUL'SNAIA AKTIVNOST' NEIRONOV TSENTRA

### TERMOREGULIATSII V USLOVIIAKH TERMONEITRAL'NOI

### ZONY]

L. P. DYMNIKOVA and M. D. CHERNOVA (AN SSSR, Institut Fiziologii, Leningrad, USSR) Fiziologicheskii Zhurnal SSSR (ISSN 0015-329X), vol. 76, June 1990, p. 789-794. In Russian. refs

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The correlation between the pulse frequency of individual neurons of the posterior hypothalamus and the variations of temperature in the hypothalamus and the skin of concha auriculae and of dorsum nasi in rabbits is investigated. Results show that, out of a total of 30 neurons tested, 15 exhibited a correlation between the impulse frequency and the temperature variations in the brain or skin. Some neurons exhibited a double correlation, where the pulse frequency correlated with both the brain and the skin temperatures. I.S.

N90-28958# Commerce Dept., Washington, DC. Japanese Technical Literature Program.

### JAPANESE MOLECULAR BIOLOGY 1990: AN UPDATE

R. B. WICKNER 1990 49 p

(PB90-188707) Avail: NTIS HC A03/MF A01 CSCL 06B

A series of summaries of the recent and current work of a number of selected top labs in molecular biology in Japan is given. Most of the work covered is not only important as basic science, but has important implications for applications. Separate brief discussions are included of the Human Genome Project, of the Human Frontiers Science Program and of some general observations on factors likely to influence the future course of the relative scientific situations in Japan and the U.S. Also presented is a summary of some of the work presented at the 12th Annual Meeting of the Japanese Society for Molecular Biology (November 29 to December 2, 1989) which the author attended during the laboratory visits in Japan. GRA

N90-28959\*# Miriam Hospital, Providence, RI. Dept. of Pathology.

### COMPUTER AIDED MECHANOGENESIS OF SKELETAL

### MUSCLE ORGANS FROM SINGLE CELLS IN VITRO

HERMAN H. VANDENBURGH, SOMPORN SWASDISON (Alabama Univ., Birmingham.), and PATRICIA KARLISCH 1990 21 p

(Contract NAG-2-414)

(NASA-CR-187025; NAS 1.26:187025) Avail: NTIS HC A03/MF A01 CSCL 06C

Complex mechanical forces generated in the growing embryo play an important role in organogenesis. Computerized application of similar forces to differentiating skeletal muscle myoblasts in vitro generate three dimensional artificial muscle organs. These organs contain parallel networks of long unbranched myofibers

organized into fascicle-like structures. Tendon development is initiated and the muscles are capable of performing directed, functional work. Kinetically engineered organs provide a new method for studying the growth and development of normal and diseased skeletal muscle.

Author

**N90-28960\***# Miriam Hospital, Providence, RI. Dept. of Pathology.

**INSULIN AND INSULIN-LIKE GROWTH FACTOR-1 INDUCE PRONOUNCED HYPERTROPHY OF SKELETAL MYOFIBERS IN TISSUE CULTURE**

HERMAN H. VANDENBURGH, PATRICIA KARLISCH, and JANET SHANSKY 1990 40 p  
(Contract NAG2-414)  
(NASA-CR-187026; NAS 1.26:187026) Avail: NTIS HC A03/MF A01 CSCL 06C

Skeletal myofibers differentiated from primary avian myoblasts in tissue culture can be maintained in positive nitrogen balance in a serum-free medium for at least 6 to 7 days when embedded in a three dimensional collagen gel matrix. The myofibers are metabolically sensitive to physiological concentrations of insulin but these concentrations do not stimulate cell growth. Higher insulin concentrations stimulate both cell hyperplasia and myofiber hypertrophy. Cell growth results from a long term 42 percent increase in total protein synthesis and a 38 percent increase in protein degradation. Myofiber diameters increase by 71 to 98 percent after 6 to 7 days in insulin-containing medium. Insulin-like growth factor-1 but not insulin-like growth factor-2, at 250 ng/ml, is as effective as insulin in stimulating cell hyperplasia and myofiber hypertrophy. This model system provides a new method for studying the long-term anabolic effects of insulin and insulin-like growth factors on myofiber hypertrophy under defined tissue culture conditions.

Author

**N90-28961\***# Total Army Personnel Agency (Provisional), Alexandria, VA.

**A DESIGN TOOL UTILIZING STOICHIOMETRIC STRUCTURE FOR THE ANALYSIS OF BIOCHEMICAL REACTION NETWORKS** Final Report M.S. Thesis - Wisconsin Univ., Madison

STEPHEN EDWARD KELLY 20 May 1990 173 p  
(AD-A223873) Avail: NTIS HC A08/MF A01 CSCL 06/1

A method is proposed for the analysis of possible distributions of products in biochemical reaction networks using linear optimization techniques. Software to assist in the conduct of this analysis was developed. Several biochemical systems were analyzed to examine the effects of different constraining situations. Software was developed to simplify and reduce the manual data manipulation needed to conduct this analysis. The software consists of two major components: a specially constructed database and a commercial linear optimization package. The database program was constructed to store and manipulate information on chemical species and on the reactions involving them. The database can assemble information about many reactions to form a stoichiometric model of a reaction network. The solution provides information on the overall reaction the network performs as well as the relative rates of the individual reactions within the network. Several biochemical reaction networks were examined. A proposed pathway for the biosynthetic production of astaxanthin, a natural red pigment was analyzed. Penicillin production was examined for the effects of various carbon and reduction/oxidation limits. The production of 1,3-propanediol (1,3-PD) was examined with the pathway for 1,3-PD overlaid onto the general metabolic pathways of Escherichia coli.

GRA

**N90-29761\***# Harvard Medical School, Boston, MA. Dept. of Physiology.

**RENAL RESPONSE TO SEVEN DAYS OF LOWER BODY POSITIVE PRESSURE IN THE SQUIRREL MONKEY**

SUSANNE CHURCHILL, DAVID M. POLLOCK, MARY ELLEN NATALE, and MARTIN C. MOORE-EDE 1987 30 p Prepared in cooperation with Institute for Circadian Physiology, Boston, MA

(Contract NAS2-10547)

(NASA-CR-183355; NAS 1.26:183355) Avail: NTIS HC A03/MF A01 CSCL 06/3

As a ground-based model for weightlessness, the response of the chair-trained squirrel monkey to lower body positive pressure (LBPP) was evaluated in a length of study similar to a typical Space Shuttle mission (7 days). Results were compared to time control experiments that included chair-sitting without exposure to LBPP. Chronic exposure to LBPP results in an acute diuretic and natriuretic response independent of changes in plasma aldosterone concentrations and produces a chronic reduction in fluid volume lasting the duration of the stimulus.

Author

**N90-29762\***# Joint Publications Research Service, Arlington, VA.  
**JPRS REPORT: SCIENCE AND TECHNOLOGY. USSR: LIFE SCIENCES**

20 Jun. 1990 27 p

(JPRS-ULS-90-007) Avail: NTIS HC A03/MF A01

Abstracts of Soviet literature in various areas of the life sciences are compiled. The following subject areas are covered: aerospace medicine, biochemistry and biotechnology, epidemiology and immunology, military medicine, pharmacology and toxicology, and radiation biology.

M.G.

**N90-29763\***# Joint Publications Research Service, Arlington, VA.  
**JPRS REPORT: SCIENCE AND TECHNOLOGY. USSR: LIFE SCIENCES**

23 Apr. 1990 39 p

(JPRS-ULS-90-004) Avail: NTIS HC A03/MF A01

Abstracts of Soviet literature in various areas of the life sciences are compiled. The following subject areas are covered: agricultural science, biochemistry, genetics, medicine, microbiology, pharmacology and toxicology, physiology, and public health.

M.G.

**N90-29764\***# Institute for Circadian Physiology, Boston, MA.

**PHARMACOLOGICAL RESETTING OF THE CIRCADIAN SLEEP-WAKE CYCLE EFFECTS OF TRIAZOLAM ON REENTRAINMENT OF CIRCADIAN RHYTHMS IN A DIURNAL PRIMATE** Final Technical Report, 1 May - 31 Oct. 1990  
Z. BOULOS and M. C. MOORE-EDE 12 Jun. 1990 12 p  
(Contract AF-AFOSR-0191-88; AF PROJ. 2312)  
(AD-A224227; AFOSR-90-0755TR) Avail: NTIS HC A03/MF A01 CSCL 06/5

An attempt was made to accelerate the reentrainment of circadian rhythms in squirrel monkeys exposed to 8-hr phase advances and phase delays of the daily light-dark cycle by timed administration of the short acting benzodiazepine, triazolam. On the day of the phase advance, each animal received a single injection of triazolam (0.3 mg) or of vehicle alone in mid-subjective day, 2 hr after the new time of dark onset, while on the day of the phase delay, the animals received triazolam or vehicle in late subjective night, just before dark onset. The daily acrophases of the circadian rhythm of body temperature were calculated by cosinor analysis, and exponential functions were fitted to the acrophases that followed each of the phase shifts. The rates of reentrainment, defined as the time required for the exponential functions to reach 90 percent of their asymptotic values, were slower after the phase advance than after the phase delay but did not differ significantly between drug and vehicle conditions.

GRA

**N90-29765\***# Massachusetts Inst. of Tech., Cambridge. Dept. of Electrical Engineering and Computer Science.

**INTERACTION OF ELECTROMAGNETIC FIELDS WITH CHONDROCYTES IN GEL CULTURE** Final Report, 1 Feb. - 22

Aug. 1989

ALAN J. GRODZINSKY, YEHEZKIEL A. GLUZBAND, and MICHAEL D. BUSCHMANN Feb. 1990 32 p  
(Contract F33615-87-D-0626; AF PROJ. 2312)  
(AD-A223397; USAFSAM-TR-89-27) Avail: NTIS HC A03/MF A01 CSCL 06/4

The research accomplished during this project period focused

## 51 LIFE SCIENCES (GENERAL)

on control experiments designed to establish whether cartilage cells from normal cartilage will continue to synthesize and accumulate normal extracellular matrix in agarose gel culture. This information is essential to properly design experiments to qualify changes in chondrocyte biosynthesis due to applied electromagnetic fields. The results suggest that both normal chondrocytes and swine rat chondrosarcoma cells in agarose culture can continue to synthesize matrix macromolecules at a rate similar to or slightly higher than that in normal cartilage; also, that chondrocytes in agarose can successfully mediate assembly and accumulation of normal, mechanically functional extracellular matrix.

GRA

**N90-29766#** Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Abt. Weltraumbiologie.

### EXOGENOUS AND ENDOGENOUS CONTROL OF ACTIVITY BEHAVIOR AND THE FITNESS OF FISH Thesis - Cologne Univ.

DIETER SEIBT 1990 161 p In GERMAN; ENGLISH summary Report will be announced as translation (ESA-TT-1221)

(DLR-FB-90-14; ISSN-0171-1342; ETN-90-97546) Avail: NTIS HC A08/MF A01; DLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Federal Rep. of Germany, HC 48 deutsche marks

The variations of the locomotive activity of the goldfish under light direction and intensity are studied. The fish were first studied in standardized conditions and were then fed at irregular intervals. An alternation light shadow cycles of variable lengths shows the influence of exogenous factors on activity. The dorsal light reaction of guppy was used for a fitness and performance test: a vertical aligning of the fish separated the light direction from the gravity orientation. Quality, precision and velocity of the orientation reactions after changes of the lighting angle were measured and examined for periodical variations.

ESA

## 52

### AEROSPACE MEDICINE

Includes physiological factors; biological effects of radiation; and effects of weightlessness on man and animals.

**A90-50701**

### THE EFFECT OF VARIOUS STRAINING MANEUVERS ON CARDIAC VOLUMES AT 1G AND DURING +GZ ACCELERATION

TOM JENNINGS (Illinois, University, Chicago), LLOYD TRIPP (USAF, Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH), LORA HOWELL (USAF, Tyndall AFB, FL), JOHN SEAWORTH (USAF, Lackland AFB, TX), DAVID RATINO (USAF, Williams AFB, AZ) et al. SAFE Journal, vol. 20, Fall 1990, p. 22-28. Research supported by USAF. refs Copyright

The purpose of this study was to evaluate the effect of Valsalva (Val), isometric contraction (Iso), and the L-1 maneuvers (L-1) on cardiac volumes at 1G and during 4G. Two-dimensional echocardiography was used to measure volumes. In the 1G phase, eight seated male subjects performed the three maneuvers. The end-diastolic volume (EDV) decreased during Val and L-1 ( $p$  not greater than 0.05). EDV decreased initially but then returned to baseline with Iso. In the 4G phase, seven male subjects experienced three 30 second 4G epochs while performing the three maneuvers. During 4G, 3 of 7 performing Val, 2 of 7 performing Iso, and none performing L-1, experienced peripheral light loss. EDV decreased and stabilized below baseline during the 4Gz epoch. Heart rate and cardiac output increased for all maneuvers. Differences between the effects of Val, Iso, and L-1 on G-tolerance do not appear to be related to a differential ability to maintain cardiac volumes. L-1 must provide more G protection

due to the isometric contraction component of the maneuver and its ability to increase blood pressure.

Author

**A90-50791**

### MODERN CONCEPTS CONCERNING HUMAN-BODY ADAPTATION TO HYPERBARIA AND ITS READAPTATION AFTER DECOMPRESSION [SOVREMENNYE KONTSEPTSIY ADAPTATSII ORGANIZMA CHELOVEKA K GIPERBARIU I EGO READAPTATSII POSLE DEKOMPRESSII]

S. A. GULIAR and V. N. IL'IN (AN USSR, Institut Fiziologii, Kiev, Ukrainian SSR) Fiziologicheskii Zhurnal (Kiev) (ISSN 0201-8489), vol. 36, July-Aug. 1990, p. 105-114. In Russian. refs Copyright

The concept of four-phase adaptation to an increased gas pressure (N<sub>2</sub> or He) is formulated on the basis of literature data and new laboratory results. It is shown that each of these phases depends on the intensity of hyperbaric stress and on the condition of the organism. A hypothesis is proposed that assumes the formation of a systemic functional and structural 'trace' in response to repeated long-time hyperbaric exposures. Changes in the system depending on periods after decompression are described. I.S.

**A90-50823**

### CIRCADIAN DYNAMICS OF THE PARAMETERS OF THE HUMAN CARDIORESPIRATORY SYSTEM DURING PHYSICAL EXERCISE AND CHANGES IN THE GASEOUS MEDIUM [TSIRKADIANNAIA DINAMIKA POKAZATELEI KARDIORESPIRATORNOI SISTEMY CHELOVEKA PRI FIZICHESKOI NAGRUZKE I V IZMENENNOI GAZOVOI SREDE]

N. A. AGADZHANIAN, A. I. ELFIMOV, and I. V. RADYSH (Universitet Druzhby Narodov, Moscow, USSR) Fiziologiya Cheloveka (ISSN 0131-1646), vol. 16, July-Aug. 1990, p. 88-96. In Russian. refs Copyright

The effects of physical load and of atmospheric changes (hypoxia and hypercapnia) on the circadian dynamics of cardiorespiratory parameters were investigated in human subjects with low (up to 2.5 W/kg body mass) and high (above 3.0 W/body mass) levels of physical work capacity. It was found that, in subjects with low levels of work capacity who were subjected to a physical load, the absolute values of minute respiratory volume (MRV) were lower than in subjects with high work capacity, while the values of the minute blood volume (MBV) were higher in the first group. Moreover, in subjects with low levels of work capacity, the MRV reaction is higher in the morning hours than in the evening, while MBV is lower in the morning; the reverse is true for subjects with high work capacity. I.S.

**A90-50824**

### CHANGES IN THE HEAT EXCHANGE AND THE NUTRITIONAL STATE OF HUMANS DURING TRANSFERS TO HOT CLIMATE REGIONS [IZMENENIE TEPLOVOGO OBMENA I STATUSA PITANIYA CHELOVEKA PRI PEREMESHCHENII V RAION S ZHARKIM KLIMATOM]

A. N. AZHAEV, P. A. LOZINSKII, and V. E. POTKIN Fiziologiya Cheloveka (ISSN 0131-1646), vol. 16, July-Aug. 1990, p. 120-124. In Russian. refs Copyright

**A90-50825**

### BODY TEMPERATURE, PLASMA CONCENTRATIONS OF CALCIUM, SODIUM, AND GLUCOSE, AND THE OSMOTIC BLOOD PRESSURE IN HUMANS DURING THE PROCESS OF ADAPTATION TO HIGH TEMPERATURES [TEMPERATURA TELA, KONTSENTRATSIIA KAL'TSIIA, NATRIIIA I GLIUKOZY V PLAZME, OSMOTICHESKOE DAVLENIE KROVI PRI ADAPTATSII CHELOVEKA K VYSOKOI TEMPERATURE]

M. D. KHUDAIBERDIEV, A. SH. AMANEKOVA, and F. F. SULTANOV (AN TSSR, Institut Fiziologii i Eksperimental'noi Patologii Aridnoi Zony, Ashkhabad, Turkmen SSR) Fiziologiya Cheloveka (ISSN 0131-1646), vol. 16, July-Aug. 1990, p. 125-129. In Russian. refs Copyright

Correlations between body temperature, plasma concentrations of calcium, sodium, and glucose, and the blood osmolarity of humans during adaptation to high summer temperatures of Turkmenia were investigated in male subjects by measuring these parameters during the months of January and June. Compared to January values, June measurements revealed significant increases in tympanic and rectal temperature and in plasma concentrations of calcium and glucose, as well as in osmolarity. On the other hand, the values of Na/Ca were lower in June. It is suggested that these humoral shifts taking place during the process of adaptation to prolonged heat exposure are directed toward stabilizing the body temperature.

I.S.

I.S.

**A90-50848****CLINICAL AND IMMUNOLOGICAL CHANGES DUE TO GENERAL HYPOTHERMIA [KLINIKO-IMMUNOLOGICHESKIE IZMENENIIA PRI OBRASHCHEM PEREOKHLAZHDENII ORGANIZMA]**

V. S. NOVIKOV and V. N. BORTNOVSKII Voenno-Meditsinskii Zhurnal (ISSN 0026-9050), July 1990, p. 21-24. In Russian.  
Copyright

The effects of hypothermia on nonspecific resistance mechanisms and on immunogenesis of the human organism were investigated in 27 crew members of the Komsomolets submarine, who survived prolonged exposure to cold water after the submarine was involved in an accident. Blood analyses in newly admitted patients showed increases in the number of leukocytes (mostly neutrophils), considered to be due to hypothermia-induced release from the bone marrow, with the extent of the increase depending on the degree of hypothermia. The ingestive and digestive activities of these leukocytes were low, however, indicating a decrease in nonspecific resistance, and remained low in spite of therapy. General hypothermia was also accompanied by significant increases of total numbers of T-cells and their subpopulations, accompanied by a fall in their functional activity.

I.S.

**A90-50849****PHARMACOLOGICAL CORRECTION BY ASPARKAM OF THE FUNCTIONAL STATE OF ARMY PILOTS IN A HOT CLIMATE [FARMAKOLOGICHESKAIA KORREKTSIIA ASPARKAMOM FUNKTSIONAL'NOGO SOSTOIANIIA LETCHIKOV ARMEISKOI AVIATSII V USLOVIIAKH ZHARKOGO KLIMATA]**

A. A. BOCHENKOV and V. A. CHVIAKIN Voenno-Meditsinskii Zhurnal (ISSN 0026-9050), July 1990, p. 62, 63. In Russian.  
Copyright

This paper discusses metabolic changes in pilots working in a hot climate (at temperatures above 35°C), together with pharmacological means of correcting hyperthermia-induced metabolic insufficiencies (as well as declines in work capacity). Special consideration is given to the effect of 'asparkam' on pilots showing characteristic symptoms of hyperthermia, such as low activity of lymphocytic succinate dehydrogenase, SDH, a decline in sodium excretion, and changes in psychophysiological indices. It was found that, after one week to a month of treatment with asparkam (one tablet three times a day), the lymphocytic SDH activity and sodium excretion increased and the psychophysiological indices began to normalize.

I.S.

**A90-50850****BIORHYTHMS AND WORK CAPACITY OF SEAMEN IN CONDITIONS OF HYPOKINESIA [BIORITMY I RABOTOSPOSOBNOST' MORIAKOV V USLOVIIAKH GIOPKINEZII]**

O. IU. NETUDYKHATKA, A. I. AKULININ, A. P. STOIANOV, and V. G. KRAVETS Voenno-Meditsinskii Zhurnal (ISSN 0026-9050), July 1990, p. 64, 65. In Russian.  
Copyright

Effects of physical exercise on the diurnal rhythms of physiological functions and work capacity of seamen during transmeridional trips are investigated in seamen whose vessels cross from one to eight time zones. Physical exercises consisted in a set of standard gymnastics and a complex of specially developed exercises including general physical training and

accessory training on an exercise bicycle. Results showed that exercise alleviated the effects of changes in biorhythms that took place during the progressive crossing of time zones (such as increased heart rate, systolic and diastolic arterial pressures, and the sensation of fatigue).

I.S.

**A90-51391****THE HEART RATE SPECTRUM IN SIMULATED FLIGHT - REPRODUCIBILITY AND EFFECTS OF ATROPINE**

WALTER N. TAPP, BENJAMIN H. NATELSON (New Jersey, University of Medicine and Dentistry, Newark; USVA, Medical Center, East Orange, NJ), and F. S. KNOX, III (U.S. Army, Aeromedical Research Laboratory, Fort Rucker, AL) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 887-892. Research supported by the U.S. Army and USVA. refs

## Copyright

The heart rate spectrum (HRS) was computed on eight pilots during simulated flight. Although respiratory-coupled heart rate variability (i.e., that produced by vagal inputs to the heart) varied threefold across volunteers, each individual volunteer's data were very stable on three test days (median coefficient of variation = 5.4 percent). Atropine rapidly reduced heart rate variability at the respiratory frequency to the noise level (i.e., 74 percent decrease from predrug levels). Although there was no significant difference in the reduction induced by a 2 mg or 4 mg dose, there was a tendency for variability at this component of the spectrum to return to normal faster following 2 mg injection than after 4 mg injection. By the morning after injection at either dose, heart rate variability at the respiration component of the HRS was back to normal, indicating complete washout of the drug. This study revealed no technical limitation to using the HRS in real life situations outside of the laboratory and suggests that the test can be used to test the efficacy of other treatments or manipulations that reduce vagal tone to the heart.

Author

**A90-51393\*** California Univ., Los Angeles.**INSTABILITY OF OCULAR TORSION IN ZERO GRAVITY - POSSIBLE IMPLICATIONS FOR SPACE MOTION SICKNESS**

SHIRLEY G. DIAMOND, CHARLES H. MARKHAM (California, University, Los Angeles), and KEN E. MONEY (National Research Council of Canada, Astronaut Program Office, Ottawa) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 899-905. refs

(Contract NAG9-179)

## Copyright

It is proposed that study of the eye torsion reflex and its behavior under novel gravitational states may possibly provide the basis for a long-sought test to predict space motion sickness (SMS). Measures of eye torsion such as ocular counterrolling and spontaneous eye torsion, were examined during hypo- and hypergravity in parabolic flight on the NASA KC-135 aircraft. Ten subjects, including two astronauts, one who had experienced SMS and one who had not, were ranked according to scores of torsional inability at 0 G and divided into two equal groups of high and low susceptibility to SMS. At 1.8 G the groups were significantly different in both the instability measure and the measure of torsional ability. No differences were detected in eye torsion in either 0 G or 1.8 G and none of the tests were significantly different in 1 G. Results suggest that tests of eye torsion on the KC-135 might differentiate those who would experience SMS from those who would not, although it is noted that this is not yet proven.

L.K.S.

**A90-51394****RIGID GAS-PERMEABLE CONTACT LENS WEAR DURING +GZ ACCELERATION**

RICHARD J. DENNIS, WILLIAM M. WOESSNER, ROBERT E. MILLER, II, and KENT K. GILLINGHAM (USAF, School of Aerospace Medicine, Brooks AFB, TX) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 906-912. refs

## Copyright

The effect of high G forces on visual acuity and on the ability

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of rigid gas-permeable lenses to maintain position on the cornea are investigated. One hyperopic and five myopic subjects were fitted with lenses made from Pasifocon C material with a specific gravity of 1.07. Two different lens diameters were compared upon the myopic subjects for centering on the cornea. Visual acuity was measured at +1 Gz, +3 Gz, +4 Gz, +6 Gz, and +8 Gz in the straight-ahead, lateral, up-gaze positions from three acuity charts. All lenses decentered down the z axis 2-3 mm at high +Gz. Visual acuity was reduced at the higher +Gz levels to similar measurements in most subjects for both the contact lens and the spectacle control rides. No lens displaced from the cornea or dislodged from the eye during any of the 25 centrifuge runs.

L.K.S.

### A90-51395 MODULATION OF CUTANEOUS FLEXOR RESPONSES INDUCED IN MAN BY VIBRATION-ELICITED PROPRIOCEPTIVE OR EXTEROCEPTIVE INPUTS

B. J. MARTIN (Institut National de la Recherche Scientifique, Vandoeuvre, France), J. P. ROLL, and M. HUGON (Aix-Marseille I, Universite, Marseille, France) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 921-928. refs

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The effects of muscle tendon or skin vibration on the early and late components of polyphasic cutaneous responses elicited in the flexor carpi radialis by electrical stimulation of the radial nerve at the wrist were studied in the human, with all muscles at rest. Both early and late flexor responses were enhanced by flexor vibration and depressed by extensor vibration; facilitation was accompanied by a reduction of latency. Furthermore, when an 'antagonist vibration response' was present, inhibition of the flexor reflexes was replaced by a facilitation. Palm skin vibration depressed both components of the flexor reflex, while dorsal or 'back-hand' skin vibration induced either a facilitation or an inhibition. In addition, back-hand vibration modified the location of the sensations evoked by electrical stimulation of the nerve. In all cases, vibratory stimulus attenuated the perceived intensity of the electrical stimulus. These observations indicate that proprioceptive or exteroceptive information can modulate the gain of the cutaneous reflex loops in a flexible way, under supraspinal control. These data also suggest a possible impairment of the protective withdrawal reflex under vibratory environmental conditions at rest and eventually in active muscles.

Author

### A90-51396 THE EFFECT OF +GZ OFFSET RATE ON RECOVERY FROM ACCELERATION-INDUCED LOSS OF CONSCIOUSNESS

CYRUS C. M. WHINNERY (U.S. Navy, Willow Grove Naval Air Station, PA) and JAMES E. WHINNERY (U.S. Navy, Naval Air Development Center, Warminster, PA) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 929-934. refs

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The effect of rapid offset from +Gz on recovery characteristics following induction of +Gz-induced loss of consciousness (G-LOC) has been investigated in order to gain a better understanding of G-LOC. Forty-two G-LOC episodes occurring on the Naval Air Development Center (NADC) centrifuge were analyzed. The study compared the incapacitation between two groups of asymptomatic men resulting from generally similar rapid onset (greater than 3Gs) +G exposure to induce GLOC but with different +Gz offset rates. The incapacitation following G-LOC with slower offset (SO) resulted in an overall incapacitation period (OIP) of 10.47 + or - 3 s, while the incapacitation of the faster offset (FO) resulted in an OIP of 7.59 + or - 3.14 s. The rate of +Gz offset also affects the time following G-LOC before onset of myoclonic convulsions, where this period was shorter for the FO group than for the SO group, yet the convolution period remained the same. It is noted that results strongly favor an ischemic/hypoxic mechanism for G-LOC.

L.K.S.

### A90-51397

#### CERVICAL DYSTONIA FOLLOWING EXPOSURE TO HIGH-G FORCES

JONATHAN B. CLARK (U.S. Navy, Naval Aerospace Medical Institute, Pensacola, FL) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 935-937. refs

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Injuries to the cervical region have been associated with high-G loads sustained during air combat maneuvering (ACM) in high performance fighter aircraft. The spectrum of injuries ranges from mild neck pain to musculoskeletal strain, injury to the nerve roots or spinal cord, and fracture of the cervical spine. A 36-year-old fighter pilot with 2,800 h in tactical jet aircraft developed progressive cervical dystonia (spasmodic torticollis), following an ACM flight. The patient was successfully treated with local intramuscular injections of botulinum toxin into the affected cervical muscles, resulting in total relief of his spasmodic torticollis. The aeromedical considerations of this rare complication of exposure to G forces in high performance aircraft are discussed.

Author

### A90-51398

#### FLIGHT CREWS WITH UPPER RESPIRATORY TRACT INFECTIONS - EPIDEMIOLOGY AND FAILURE TO SEEK AEROMEDICAL ATTENTION

TIMOTHY J. UNGS and SATYA P. SANGAL (USCG, Support Center, Kodiak, AK; Wright State University, Dayton, OH) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 938-941. refs

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### A90-51399

#### MILITARY AVIATION - A CONTACT LENS REVIEW

MORRIS R. LATTIMORE, JR. (U.S. Army, Aeromedical Research Laboratory, Fort Rucker, AL) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Oct. 1990, p. 946-949. refs

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The military aviation communities have benefitted from the development of advanced electro-optical avionics systems. One drawback that has emerged is an increasing system incompatibility with traditional spectacle visual corrections. An alternative solution to the refractive error correction problem that some services have been investigating is that of contact lens wear. Since this much-debated topic is currently of command interest, a general overview of contact lens issues is presented as a framework for future discussions.

Author

### A90-51666

#### EFFECTS OF MICROGRAVITY ON MICROCIRCULATION

S. N. MAJHI and V. R. NAIR (Indian Institute of Technology, Madras, India) Microgravity Science and Technology (ISSN 0938-0108), vol. 3, Sept. 1990, p. 117-120. refs

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The blood behavior in human circulatory system observed during space flights reveals that the microgravity environment reduces the flow rate and increases the haematocrit compared with the situation on the earth surface. The present study gives a theoretical analysis of the above phenomena by considering a two-layer Newtonian model for blood flow in capillaries. The effect of gravity on plasma layer as well as on the blood viscosity is taken into account for calculating the percentage change in flow rate of blood. The corresponding apparent viscosities on the earth surface and in space are estimated. The results are analyzed and presented graphically. The findings agree reasonably well with the data observed in spaceflight experiments.

Author

N90-28962# Midwest Research Inst., Kansas City, MO.

#### FURTHER STUDIES OF 60 HZ EXPOSURE EFFECTS ON HUMAN FUNCTION Quarterly Report No. 4, 1 Apr. - 30 Jun.

1990

CHARLES GRAHAM and HARVEY D. COHEN 20 Jul. 1990  
7 p

(Contract DE-FG01-89CE-34025; MRI PROJ. RA-111-C)

(DE90-014377; DOE/CE-34025/T4) Avail: NTIS HC A02/MF A01

Public concern has been expressed about possible health risks arising from exposure to the electric and magnetic fields generated by power distribution systems. This project is addressing this concern through a laboratory research program designed to evaluate the effects of brief exposure to known field conditions on multiple measures of human function. In this continuation effort, a series of exploratory studies are being performed, which will be followed by a confirmatory experiment, to determine if the above physiological effects differ as a function of exposure to the electric and magnetic fields separately and combined, time of day, and rate of intermittent exposure. Project status to date is as follows. An initial series of exploratory studies, involving 24 healthy male volunteers exposed over multiple sessions, was completed. These studies assessed whether effects on human physiology differ over the day as a function of intermittent exposure to the electric vs. the magnetic fields. Exposure to the magnetic fields produced a pattern of cardiac changes similar to that observed in our previous research. This pattern was not found when subjects were exposed to the electric field. Goals were to: continue performance of the probe studies; and present project findings at the 1990 meeting of the Bioelectromagnetics Society (BEMS). DOE

N90-28963\* National Aeronautics and Space Administration, Washington, DC.

#### AEROSPACE MEDICINE AND BIOLOGY: A CONTINUING BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 340)

Feb. 1989 64 p

(NASA-SP-7011(340); NAS 1.21:7011(340)) Avail: NTIS HC A03; NTIS standing order as PB90-912300, \$11.50 domestic, \$23.00 foreign CSCL 06/5

This bibliography lists 157 reports, articles and other documents introduced into the NASA Scientific and Technical Information System during August 1990. Subject coverage includes: aerospace medicine and psychology, life support systems and controlled environments, safety equipment, exobiology and extraterrestrial life, and flight crew behavior and performance. Author

N90-28964# Bordeaux 2 Univ. (France). U.F.R. des Sciences Medicales.

#### CARDIOVASCULAR DECONDITIONING OF COSMONAUTS: ROLE, IMPORTANCE AND APPLICATIONS OF THE LOWER BODY NEGATIVE PRESSURE Ph.D. Thesis [LE DECONDITIONNEMENT CARDIO VASCULAIRE CHEZ LES COSMONAUTES: ROLES, INTERETS ET APPLICATIONS DU LOWER BODY NEGATIVE PRESSURE]

LAURENT LABREZE 1990 178 p In FRENCH Original contains color illustrations

(ETN-90-97507) Avail: NTIS HC A09/MF A01

Microgravity effects on the cardiovascular system of cosmonauts are investigated. Experiments using the lower body negative pressure system are performed. Modifications in the cardiovascular system when the body is placed under microgravity conditions are studied. The consequences of the cardiovascular deconditioning syndrome under normal gravity conditions are examined. Special attention is given to the orthostatic intolerance. The importance of the lower body negative pressure device in future space missions is underlined. ESA

N90-28965\*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

#### JOINT US/USSR STUDY: COMPARISON OF EFFECTS OF HORIZONTAL AND HEAD-DOWN BED REST

HAROLD SANDLER and ANATOLI I. GRIGORIEV (Institute of Biomedical Problems, Moscow, USSR ) Washington Aug. 1990

102 p

(NASA-TP-3037; A-85177; NAS 1.60:3037) Avail: NTIS HC A06/MF A01 CSCL 06/19

An account is given of the results of the first joint U.S./U.S.S.R. bed rest study. The study was accomplished in two parts: A soviet part (May to June 1979) and an American part (July to August 1979). Both studies were conducted under identical conditions

and provided a basis for comparison of physiologic reactions and standardizing procedures and methods. Each experiment consisted of three periods: 14 days of pre-bed rest control, 7 days of bed rest, and a 10 to 14 day recovery period. Ten males participated in each study, with five subjects experiencing horizontal bed rest and five subjects a -6 deg head-down body position. Biochemical and hormonal measurements were made of blood and urine, with particular attention to electrolyte metabolism and kidney function; cardio-pulmonary changes at rest and exercise; influence of Lower Body Negative Pressure (LBNP); and incremental exercise using a bicycle ergometer while supine and sitting. Expected moderate changes were noted to occur for various physiologic parameters. Clinical evidence pointed to the fact that head-down bed rest when compared to horizontal conditions more closely matched the conditions seen after manned spaceflight. For the most part, statistically significant differences between the two body positions were not observed.

Author

N90-28966# Brookhaven National Lab., Upton, NY.

#### DNA DAMAGE AND REPAIR IN HUMAN SKIN: PATHWAYS AND QUESTIONS

B. M. SUTHERLAND, H. HACHAM, J. C. SUTHERLAND, R. W. GANGE, and D. MAYTUM (Harvard Medical School, Boston, MA.) 1989 12 p Presented at the DNA Damage and Repair in Human Tissues Conference, Upton, NY, 1-4 Oct. 1989 Sponsored in part by Wellman Foundation (Contract DE-AC02-76CH-00016)

(DE90-015126; BNL-44839; CONF-8910354-2; BIO-4595) Avail: NTIS HC A03

Skin is assaulted daily with physical and chemical carcinogens, promoters, and modifiers of biological responses to such agents. DNA is the principal target for most carcinogens, and DNA in skin is particularly at risk. It is subject to damage not only from ingested compounds and their metabolic products, but also from externally applied or encountered chemicals, as well as from physical carcinogens such as sunlight and cosmetic or medical sources of ultraviolet radiation. Three major factors determine the balance between damage to DNA of skin and the biological consequences of that damage: the frequencies and types of lesions, the ability of the individual to repair a lesion, and the strategy that skin employs to deal with the different spectra of lesions inflicted under varying environmental conditions. Thus, cellular responses to DNA damage, including repair of DNA lesions, are critical factors in determining the final level of damage and its consequences. This paper discusses DNA damage and repair in human skin. DOE

N90-28967# School of Aerospace Medicine, Brooks AFB, TX.

#### DECOMPRESSION SICKNESS PRESENTING AS A VIRAL SYNDROME Final Report

FREDERICK W. RUDGE 1989 8 p

(AD-A223880; USAFSAM-JA-90-22) Avail: NTIS HC A02/MF A01 CSCL 06/5

Decompression sickness (DCS) is a well-known hazard of exposure to significant variations in ambient pressure. The diagnosis and management of DCS is frequently a source of confusion. Although the majority of cases are manifested by joint or limb pains (Type I DCS), patients may present with a wide array of symptoms, such as neurologic deficits, headache, fatigue, nausea, and respiratory difficulty. A thorough knowledge of the differential diagnosis and a strong index of suspicion are crucial to the proper management of DCS. Presented herein are two cases of altitude-related DCS which were confused initially with a viral syndrome. A discussion of the symptoms of DCS is included.

GRA

N90-28968# Naval Health Research Center, San Diego, CA.

#### PREVALENCE OF HYPERTENSION AMONG ACTIVE DUTY PERSONNEL Interim Report

D. STEPHEN NICE and LINDA KELLY TRENT 13 Apr. 1990 20 p

(AD-A223892; NHRC-90-5) Avail: NTIS HC A03/MF A01 CSCL 06/5

The prevalence of uncontrolled hypertension in the Navy was

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studied. Systolic and diastolic blood pressure readings were collected for 10,866 active duty men and women in conjunction with the Navy's current blood pressure screening program. Mean systolic blood pressure was 118.3 (millimeters of mercury) mmHg; mean diastolic blood pressure was 71.6 mmHg. Blood pressure was elevated in 8.9 percent of the total sample, which is lower than the adjusted rate for the nation at large (about 14 percent). Hypertension was more prevalent among enlisted personnel, older individuals, men, and blacks. The relatively low prevalence of hypertension in the Navy may be related to screening policies at accession and/or the Navy's ongoing health and fitness programs, including exercise, weight control, and nutrition. However, with nearly 1 in 10 sailors exhibiting high blood pressure, it is recommended that the Navy continue its efforts toward a comprehensive program for detection and treatment of hypertension.

GRA

**N90-28969#** Florida Univ., Gainesville. Dept. of Psychology.  
**COMPLEX AUDITORY SIGNALS Annual Report, 14 Apr. 1989 - 15 Apr. 1990**

DAVID M. GREEN and BRUCE G. BERG 13 Jun. 1990 7 p  
(Contract AF-AFOSR-0333-88; AF PROJ. 2313)  
(AD-A224127; AFOSR-90-0749TR) Avail: NTIS HC A02/MF A01  
CSCL 25/4

Efforts to understand the perception of complex auditory stimuli produced four different research undertakings. Studies have been done both with computer simulations and human listeners, the most precise psychophysical procedure to estimate a discrimination threshold. A technique to determine the listener's sensitivity to synchrony was perfected in envelope modulation produced at two separate regions, and have measured such sensitivity using a variety of different stimulus parameters. Sensitivity to modulation synchrony is essentially independent of the locus of the two frequency bands. Studies have also been done on temporal factors that influence the ability to discriminate an increment in the level of a single component of a multi-tonal complex. Very slight differences in the temporal onset (greater than 20 msec.) of tone and complex strongly influence the ability to make such discrimination even when the entire stimulus lasts 500 msec. Finally, we continue to study the estimates of spectral weights used in such intensity discrimination tasks.

GRA

**N90-28970#** Loyola Univ., Chicago, IL. Hearing Inst.  
**AUDITORY PROCESSING OF COMPLEX SOUNDS ACROSS FREQUENCY CHANNELS Annual Technical Report, 1 May 1989 - 30 Apr. 1990**

WILLIAM P. SHOFNER, RAYMOND H. DYE, WILLIAM A. YOST, and STANLEY SHEFT 24 May 1990 7 p  
(Contract AF-AFOSR-0335-89; AF PROJ. 2313)  
(AD-A224147; AFOSR-90-0754TR) Avail: NTIS HC A02/MF A01  
CSCL 06/4

Neurophysiological experiments have been directed at gaining an understanding of how auditory neurons encode pitch related information in the temporal properties of discharge. In general, all physiological neuronal types recorded to date in the chinchilla cochlear nucleus can show periodicities in their discharges that are related to the pitch of harmonic tone complexes, but only those neurons that show phase-locking at best frequency can encode the pitch related information in cost + rippled noise. The results of binaural psychophysical experiments suggest: (1) that spectrally synthetic binaural processing is the rule when the number of components in the tone complex are relatively few (less than 10) and there are no dynamic binaural cues to aid segregation of the target from the background, and (2) that waveforms having large effective envelope depths are on the average more easily lateralized than those having small effective envelope depths.

GRA

**N90-28987#** Hamburg Univ. (Germany, F.R.). Dept. of Eyes.  
**EXPERIMENTAL TESTS ON THE MINIMAL VISUAL ACUITY REQUIRED FOR SAFE AIR CREW AND AIR CONTROL PERSONNEL PERFORMANCE**

J. DRAEGER and R. SCHWARTZ /n AGARD, Situational

Awareness in Aerospace Operations 3 p Apr. 1990  
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National and international directives specify minimal requirements for corrected and uncorrected visual acuity in military as well as civil aviation. There is a striking difference between the corrected visual acuity and the minimal visual acuity specified as a lower limit. The present experimental study concerning military pilots deals intensively with the minimal requirements on visual acuity which guarantee the safe operation of an aircraft. The investigation revealed that the specified visual acuity without correction as stated in all directives is not acceptable as a lower border limit for safe operation of an aircraft. It would therefore be possible to dispense completely with specified minimal uncorrected visual acuity values. However, a safe wearing of visual aids at all times, considering cockpit environment specific conditions must then be guaranteed. For air control personnel the uncorrected visual acuity should not have further significances. In additional studies we examined the minimal requirements for the radar controller. While reducing the visual acuity in defined steps the radar controller had to recognize critical situations during a simulated approach. For the special situation of the tower controller a visual acuity of 1.0 is required. The tests with radar controllers reveal that a reduced visual acuity between 0.5 and 1.0 had no significant influence on the failure rates. The visual acuity in that range is not as important as for pilots and tower personnel.

Author

**N90-28991#** Institute of Aviation Medicine, Madrid (Spain).  
**EVALUATION OF THE PERFORMANCE CAPABILITY OF THE AVIATOR UNDER HYPOXIC CONDITIONS OPERATIONAL EXPERIENCE**

FRANCISCO RIOS TEJADA, LUIS MARQUEZ DELAPLATA, CESAR ALONSO RODRIGUEZ, and JUAN J. CANTON ROMERO /n AGARD, Situational Awareness in Aerospace Operations 6 p Apr. 1990

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Performance capacity under hypoxia conditions was determined in 48 subjects exposed to a simulated altitude of 25,000 feet (7,620 mts.). The method was a modified Toulouse-Pieron Test (TTM) and a Digit Span Test (DST), completed at 3 altitudinal conditions: Ground Level (GL), FL 250 and Placebo (PL). Maximum hypoxia time was 4 minutes and it was measured every 30 sec. The Direct Partial Score (DPS) 8 times through the 4 min., and the Direct Total Score (DTS) was obtained by the Tolouse application formula. Significant decrements in test performance were found by comparing GL to FL 250 and FL 250 to PL in pairs at .001 confidence level after point 90 sec. time for DPS. Similar results were obtained for DTS. For DTS, the comparative analysis of the average values were also significant. The application of the TTM is considered as useful, simple and profitable in the evaluation of Attention Capacity of the aviator under hypoxia conditions. The Incapacitation Curve is a term which expresses, in a quantitative and chronological way, the psychomotor performance. Both, the TTM and DTS, are between each other complementary tools in the evaluation of the psychomotor pilot efficiency.

Author

**N90-28992#** McGill Univ., Montreal (Quebec).  
**EFFECTS OF SHORT-TERM WEIGHTLESSNESS ON ROLL CIRCULARVECTION**

D. G. D. WATT and J. P. LANDOLT /n AGARD, Situational Awareness in Aerospace Operations 6 p Apr. 1990 Sponsored in part by Medical Research Council of Canada and National Research Council of Canada Prepared in cooperation with Defence and Civil Inst. of Environmental Medicine, Toronto, Ontario  
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Roll circularvection is an illusion of self-rotation about the

fore-aft axis experienced when a stationary subject is exposed to a visual field rotating in the frontal plane. In these experiments, subjects were asked to estimate the strength of this phenomenon while undergoing visual stimulation in the upright and supine positions, and during parabolic aircraft flight. The results indicate that the steady roll component ofvection is not affected by the magnitude or direction of the gravity vector. The unpredictable and sudden loss of this compelling illusion could contribute to serious episodes of pilot disorientation. Author

**N90-28993#** Naval Aerospace Medical Research Lab., Pensacola, FL.

**MAINTAINING SPATIAL ORIENTATION AWARENESS**

A. RUPERT, A. MATECZUN, and F. E. GUEDRY, JR. *In AGARD, Situational Awareness in Aerospace Operations* 5 p Apr. 1990 Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

It is believed that training paradigms which vividly demonstrate to pilots the need and way to maintain spatial orientation awareness during formation flight will reduce the incidence of these very costly mishaps. Several training paradigms are under development using the Dynasim, a cockpit mounted on a short-arm centrifuge. The pilot controls both pitch and roll axes of the Dynasim cockpit to maintain the position on a wing aircraft projected onto a visual surround. Pilot's attention is intermittently distracted from the lead aircraft and from attitude display(s) by simultaneous performance of other cockpit tasks. The orientation experienced by pilots is controlled by varying information in the visual surround and in the onboard instruments (including a Malcolm Horizon) and by controlling the direction of the gravito inertial field of the short-arm centrifuge. A second stage of the research will investigate new concepts in displays to improve pilot orientation awareness. The inevitable distraction of visual attention, which accompanies emergency situations, engenders consideration of peripheral vision and nonvisual channels to convey aircraft attitude and target information and maintain spatial orientation awareness. Author

**N90-29767#** Naval Aerospace Medical Research Lab., Pensacola, FL.

**VESTIBULAR RESPONSES AND MOTION SICKNESS DURING PITCH, ROLL, AND YAW SINUSOIDAL WHOLE-BODY OSCILLATION** Interim Report

F. E. GUEDRY, J. NORMAN, G. TURNIPSEED, and A. RUPERT Mar. 1990 16 p  
(AD-A223898; NAMRL-1352) Avail: NTIS HC A03/MF A01 CSCL 06/10

The vestibulo-ocular reflex and motion sickness were evaluated in 5 groups of 15 men during low frequency sinusoidal whole-body oscillation about an earth-vertical axis. Head and body configurations differed between groups so that the amount of vertical canal stimulation received was varied over groups. Significant differences were found for the long time constant of the vestibulo-ocular reflex between pitch- and roll-axis stimuli. The long constant is short for the pitch axis, intermediate for the roll axis, and long for the yaw axis. Motion sickness appeared to be related to the amount of vertical semicircular canal stimulation received, with no clear difference between roll-axis and pitch-axis groups. GRA

**N90-29768#** Texas Univ., San Antonio.

**MULTI-USER FACILITY FOR HIGH PERFORMANCE OPTICAL RECORDING OF BRAIN ACTIVITY (DURIP)** Final Report, 1 Dec. 1988 - 30 Nov. 1989

DAVID M. SENSEMAN 1 Jun. 1990 9 p  
(Contract AF-AFOSR-0118-89; AF PROJ. 3842)  
(AD-A223491; AFOSR-90-0683TR) Avail: NTIS HC A02/MF A01 CSCL 15/5

This equipment grant provided funds to purchase a Silicon Graphics workstation for optical recording of brain activity. The system is being used by scientists at the University of Texas and the USAF School of Aerospace Medicine to examine brain electrical activity related to aerospace environmental stresses. GRA

**N90-29769#** Minnesota Univ., Duluth.

**EVALUATION OF PHYSIOLOGICAL AND PSYCHOLOGICAL IMPAIRMENT OF HUMAN PERFORMANCE IN COLD STRESSED SUBJECTS** Midterm Report, 9 May 1988 - 8 Nov. 1989

L. E. WITTMERS and RICHARD G. HOFFMAN 23 Mar. 1990 170 p  
(Contract DAMD17-88-C-8054; DA PROJ. 3E1-62787-A-879)  
(AD-A223635) Avail: NTIS HC A08/MF A01 CSCL 06/5

The data presented here deals with the physiological and psychological responses of man (13 subjects) to cold exposure (0 C) and added stresses. The additional stresses included cold water (15 C-mid thigh), sleep deprivation (24 hr) and exercise (70 percent maximum heart rate). Cardiovascular and respiratory parameters were monitored throughout the experiments. Urinary catecholamine excretion was determined to estimate stress levels. Skin and rectal temperatures were continuously monitored to evaluate temperature regulation. EMG monitoring was used to study the onset, pattern and magnitude of shivering in seven muscle groups. Four methods for short term shiver suppression were evaluated under the five experimental protocols. Cognitive function and rifle shooting performance were evaluated. Shooting performance and cognitive function were not significantly affected by additional stressors.

GRA

**N90-29770#** Naval Health Research Center, San Diego, CA. Dept. of Sleep Research.

**MINIMAL SLEEP TO MAINTAIN PERFORMANCE: SEARCH FOR SLEEP QUANTUM IN SUSTAINED OPERATIONS** Interim Report

PAUL NAITO 30 Nov. 1989 29 p Sponsored by Naval Research and Development Command, Bethesda, MD  
(AD-A223815; NHRC-89-49) Avail: NTIS HC A03/MF A01 CSCL 06/4

In many civilian and military occupations, personnel are required to work on a job until it is completed, even if such requirements demand continuous work for a period longer than 24 hours and/or irregular work under irregular schedules, so that sleep becomes too disrupted and too short to allow the worker to recuperate from daily fatigue. The disruption of sleep results in the worker's reduced productivity and increased risks of error or injury at work sites. In this paper, applications of sleep management are proposed to minimize degradation in work performance and to improve job safety. The basic knowledge of sleep management is discussed in detail, supplementing a sleep management guideline previously published (Naitoh, Englund and Ryman, 1986). Some of the key questions of sleep management are to determine minimal sleep duration, to evaluate impact of time of day when sleep is taken on recuperative power of sleep, and to measure individual differences in sleep habits. GRA

**N90-29771#** Naval Health Research Center, San Diego, CA. **OPTIMISM AND CARDIOVASCULAR REACTIVITY TO PSYCHOLOGICAL AND COLD PRESSOR STRESS** Final Report

C. N. LEAKE, A. W. LANGER (Syracuse Univ., NY.), C. E. ENGLUND, and M. SINCLAIR 27 Dec. 1989 19 p Sponsored by Naval Medical Research and Development Command, Bethesda, MD  
(AD-A223818; NHRC-89-53) Avail: NTIS HC A03/MF A01 CSCL 06/4

The relationship between optimism, as measured by the Life Orientation Test (LOT), and the response to mental arithmetic (MA) and cold pressor (CP) stressors was examined in 35 men. Reactivity measurements included heart rate (HR), systolic (SBP) and diastolic (DBP) blood pressure, oxygen consumption (V), minute ventilation (VE), and plasma (CORT). In order to clarify the importance of optimism to reactivity, additional assessments were made for hostility, depression, behavior type, and trait anger and anxiety. Both stressors elicited significant cardiovascular, pulmonary and cortisol responses ( $P$  less than 0.005) with the magnitude of response being greater for the CP task. Significant Pearson Correlations were found between LOT and CP reactivity for VE (r

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= .285, P less than 0.05), and MA reactivity for HR ( $r = .281$ , P less than 0.05) and VE ( $r = .374$ , P less than 0.01) yet the results suggest that optimism was not strongly associated to reactivity elicited by either stressor. However, results did indicate that the relationship between optimism and cardiovascular reactivity may be as important as those exhibited by other psychological parameters.

GRA

**N90-29772#** Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.

### FREQUENCY AND VENTILATION: A SURVEY OF THEORETICAL AND EXPERIMENTAL VENTILATION MODELLING

F. H. C. DEJONGH Apr. 1990 46 p  
(LR-625; ETN-90-97636) Avail: NTIS HC A03/MF A01

The establishment of a relation between ventilation efficiency and frequency is a final goal. A first step in this process is the construction of a lung model. The lung model contains many material, geometrical and flow parameters. Obviously a simple model is preferred. Therefore some insight in the influence of the various material, geometrical and flow parameters in the lung model on the output quantities has to be obtained. In order to get this insight a computer program is constructed to analyze the influence of the various parameters in a human lung. The output quantities are for instance: concentration of the different gases, pressure drop across the bronchii, flow velocities and diffusion rates. The conditions to be analyzed are normal ventilation, maximum expiration and high frequency ventilation occurring in human beings in the range from early born infants to adults. A survey of existing lung models for the different aspects of respiration to be studied, is given. The applicability in the computer program is emphasized.

ESA

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### BEHAVIORAL SCIENCES

Includes psychological factors; individual and group behavior; crew training and evaluation; and psychiatric research.

#### A90-50822

### SUPERSLOW FLUCTUATIONS OF CNS FUNCTIONAL STATE INDICES AND THE SPEED CHARACTERISTICS OF THE PROBLEM-SOLVING PROCESS [SVERKHMEDLENNYE KOLEBANIIA POKAZATELEI FUNKSIONAL'NOGO SOSTOIANIIA TSNS I SKOROSTNYE KHARAKTERISTIKI PROTSESSA RESHENIIA ZADACH]

G. A. AMINEV and A. R. KUDASHEV (Bashkirskii Gosudarstvennyi Universitet, Ufa, USSR) Fiziologiya Cheloveka (ISSN 0131-1646), vol. 16, July-Aug. 1990, p. 21-25. In Russian. refs

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A hypothesis according to which the dynamics of the problem-solving process is related to different frequency spectra of slow rhythms is verified experimentally by registering the latent period fluctuations of a simple videomotor reaction in subjects receiving short light stimuli at regular intervals. The intellectual process was assessed by offering the subject a series of equivalent computer game problems. It was found that the 20-sec periodic components of slow rhythms possess the most pronounced latent-period fluctuations. The appearance of 13-14-sec periodicities is one of the conditions for a rapid guess of the equivalence of the solutions, while the 1.5-2.5-min fluctuation periods are related to the rapidity with which the intellectual skill could be learned.

I.S.

**A90-52258\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### PERCEPTUAL-COMPONENTS ARCHITECTURE FOR DIGITAL VIDEO

ANDREW B. WATSON (NASA, Ames Research Center, Moffett

Field, CA) Optical Society of America, Journal, A: Optics and Image Science (ISSN 0740-3232), vol. 7, Oct. 1990, p. 1943-1949, 1951-1954. Research supported by NASA. refs

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A perceptual-components architecture for digital video partitions the image stream into signal components in a manner analogous to that used in the human visual system. These components consist of achromatic and opponent color channels, divided into static and motion channels, further divided into bands of particular spatial frequency and orientation. Bits are allocated to an individual band in accord with visual sensitivity to that band and in accord with the properties of visual masking. This architecture is argued to have desirable features such as efficiency, error tolerance, scalability, device independence, and extensibility.

Author

#### A90-52260

### VISUAL SEARCH FOR COLOR DIFFERENCES WITH FOVEAL AND PERIPHERAL VISION

ALLEN L. NAGY, ROBERT R. SANCHEZ, and THOMAS C. HUGHES (Wright State University, Dayton, OH) Optical Society of America, Journal, A: Optics and Image Science (ISSN 0740-3232), vol. 7, Oct. 1990, p. 1995-2001. refs

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Color differences required for fast parallel searches were measured for small and large display fields. The main purpose of the measurement was to test the hypothesis that serial searches obtained with small color differences in large display fields are due to poor discrimination in the peripheral visual field and to the need for foveal fixation. Results do not support this hypothesis but show that the color differences required for parallel search are just as large in a display confined to an area roughly the size of the fovea as in a large display. However, results also show that the color difference required for a fast, parallel search is dependent on the size of the stimuli in a large display field. This result is consistent with the possibility that poor discrimination in the periphery may contribute to the size of the required differences if the stimuli are small.

Author

**N90-28971#** Rochester Univ., NY. Dept. of Computer Science. TIME, SPACE AND FORM IN VISION

JEROME A. FELDMAN Nov. 1988 72 p  
(Contract N00014-84-K-0655; NSF DCR-83-20136)

(AD-A213889; TR-244) Avail: NTIS HC A04/MF A01; also avail. as TR-88-011, International Computer Science Inst., 1947 Center St., Suite 600, Berkeley, CA CSCL-23/3

The prodigious spatial capabilities of the primate visual system are even more remarkable when temporal considerations are taken into account. Recent advances in neurophysiology, psychophysics and computer vision provide significant constraints on how the system could work. This paper presents a fairly detailed connectionist computational model of how the perception and recognition of objects is carried out by primate brains. The model is claimed to be functionally adequate and to satisfy all the constraints established by the various disciplines. One key notion introduced is a multi-input, multi-output network for inverting spatio-temporal cues. The central construct in intermediate level vision is taken to be the trajectory and these are used in recognition of dynamic situations called scenarios. The entire development is an extension of the author's 1985 Four Frames model, which required relatively little modification to accommodate temporal change (eventually).

GRA

**N90-28972#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

### SITUATIONAL AWARENESS IN AEROSPACE OPERATIONS

Apr. 1990 200 p In ENGLISH and FRENCH Symposium held in Copenhagen, Denmark, 2-6 Oct. 1989

(AGARD-CP-478; ISBN-92-835-0554-9) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Symposium examined aviator situational awareness with consideration of conditions where problems occur, methods to

assess situational awareness and latest methods for information management and presentation in the cockpit. Indications for future research needs were discussed. These Proceedings will be of interest to those involved with human perception and cognition and those responsible for design of modern aircraft cockpits.

**N90-28973#** Netherlands Aerospace Medical Centre, Soesterberg.

**SPATIAL DISORIENTATION INCIDENTS IN THE RNLAF F16**

**AND F5 AIRCRAFT AND SUGGESTIONS FOR PREVENTION**

A. KUIPERS, A. KAPPERS, C. R. VANHOLLEN, J. H. W. VANBERGEN, and W. J. OOSTERVELD (Amsterdam Univ., Netherlands) *In AGARD, Situational Awareness in Aerospace Operations* 16 p Apr. 1990

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Controlled flight into terrain caused several accidents within the Royal Netherlands Airforce. Two hundred and nine RNLAF fighter pilots were interviewed to obtain information about the occurrence of spatial disorientation in flight. The incident, which left the greatest impression on each pilot, was analyzed. Thirty-four percent of those incidents is considered by the aviators as a very serious risk for flight safety. The incidents are caused by a combination of factors, of which weather conditions, psychological factors and visual reference are the most important. Visual and vestibular illusions are common, as well as certain psychological conditions which lead to a wrong perception of position or motion. The aspects of the sensation of disorientation are described in detail. All pilots have experienced disorientation in some way and 26 percent report that it has caused one or more narrow escapes. Seventy-three percent of the pilots report a greater susceptibility for disorientation in a F16, compared with other types of aircraft. Suggestions for prevention of disorientation accidents are given.

Author

**N90-28974#** Northrop Corp., Hawthorne, CA. Aircraft Div.

**A METHODOLOGY FOR THE OBJECTIVE MEASUREMENT OF PILOT SITUATION AWARENESS**

MICA R. ENDSLEY *In AGARD, Situational Awareness in Aerospace Operations* 9 p Apr. 1990

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The ability of the pilot to maintain situation awareness is recognized in the pilot community as crucial to mission success and survivability. The design of the pilot vehicle interface must therefore be guided by the goal of maintaining and enhancing pilot situation awareness. A formal definition of situation awareness is presented in addition to a detailed description of the Situation Awareness Global Assessment Technique (SAGAT). SAGAT was developed as an objective measure of a pilot's situation awareness, including pilot knowledge of ownship status, the tactical environment, his overall comprehension of the situation, and his ability to project the tactical situation into the near future. SAGAT allows for a variety of system design concepts to be evaluated on the basis of situation awareness, as well as workload and performance, thus providing the design community with a much needed tool.

Author

**N90-28975#** Royal Air Force Inst. of Aviation Medicine, Farnborough (England).

**SITUATIONAL AWARENESS RATING TECHNIQUE (SART):**

**THE DEVELOPMENT OF A TOOL FOR AIRCREW SYSTEMS DESIGN**

R. M. TAYLOR *In AGARD, Situational Awareness in Aerospace Operations* 17 p Apr. 1990

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Human engineering activities in aircrew system design traditionally were concerned with the reduction and management of operator workload. Recent advances in automation technology

have radically changed the role of the human operator and highlighted the essential human function for making adaptive decisions in situations involving uncertainty. Improving and enhancing operator situational awareness has become the major crew station design driver for achieving survivability and mission effectiveness criteria. How aircrew understand situational awareness (SA) is investigated and tools were developed for its subjective estimation.

Author

**N90-28976#** Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.

**PERFORMANCE-BASED MEASURES OF MERIT FOR**

**TACTICAL SITUATION AWARENESS**

MICHAEL VENTURINO, WILLIAM L. HAMILTON, and STEPHEN R. DVORCHAK (Hamilton and Associates, Las Vegas, NV.) *In AGARD, Situational Awareness in Aerospace Operations* 5 p Apr. 1990

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Pilot situation awareness is not a well-understood concept. Most attempts at understanding situation awareness have relied almost exclusively on subjective reports, and have not led to a clear understanding of the concept. A performance based approach to assessing situation awareness, where the relationship between pilot-reported situation awareness and tactical task performance is investigated is represented. Aspects of a high realism air combat simulation were analyzed in terms of a priori hypotheses regarding performance of a tactical task (fire point selection), its relation to pilot-reported situation awareness, and its relation with mission outcome. Results showed that pilot-reported situation awareness by itself was not a reliable indicator of pilot performance (based on mission outcome). Further, pilot performance by itself was not systematically related to fire point selection. Only when the simultaneous operation of pilot performance, fire point selection, and pilot-reported situation awareness are considered does a systematic relationship emerge. The highest mission performance scores were associated with both a FPS within a preferred zone (80 to 100 percent RMAX2) and high pilot-reported SA ratings. Lower performance scores were observed as pilots' FPS diverged from the preferred FPS area and reported lower SA scores. The drop-off in mission performance is more severe when pilots launched their weapons inside the 80 to 100 percent RMAX2 area relative to launching outside this preferred area. These findings are interpreted in terms of fire point selection as one potential measure of merit for tactical situation awareness.

Author

**N90-28977#** Royal Air Force Inst. of Aviation Medicine, Farnborough (England).

**EVALUATION OF THE SITUATIONAL AWARENESS RATING TECHNIQUE (SART) AS A TOOL FOR AIRCREW SYSTEMS DESIGN**

S. J. SELCON and R. M. TAYLOR *In AGARD, Situational Awareness in Aerospace Operations* 8 p Apr. 1990

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The Situational Awareness Rating Technique (SART) was developed as an evaluation tool for aircrew systems design. SART provides subjective estimates of attentional Demand and Supply, and ratings of Understanding, which are postulated to be the three primary components of situational awareness. While consistent with contemporary theories of cognition, the application of SART requires knowledge of performance. SART sensitivity seems likely to depend on the contribution of skill, rule, and knowledge based behavior, and on-the-role-of-explicit-and-implicit-knowledge-in-the candidate task situation. An evaluation of SART in three aircrew systems design studies with different task requirements is reported: (1) Multiple Task Compatibility Study; (2) Attitude Recovery/Attention-Switching Study; and (3) Warnings Comprehension Study. SART Demand, Supply, and Understanding ratings showed significant effects of experimental manipulations in all three studies. The relevance of the specific SART components

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was related to the contribution of skill, rule, and knowledge based behavior to the tasks. The SART ratings also highlighted weaknesses in the performance measures and improved their interpretation. Thus, in combination with performance measures, SART provides a powerful tool for aircrew system design.

Author

**N90-28978# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.**

### ATTENTION GRADIENTS IN SITUATION AWARENESS

MARTIN L. FRACKER /n AGARD, Situational Awareness in Aerospace Operations 10 p Apr. 1990

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A model of how people develop and maintain awareness was explored in a series of four experiments. These experiments focused on the role of attention allocation in situation awareness. All four experiments supported the hypothesis that attention is limited in supply contrary to recently proposed unlimited supply theories. Unlimited supply theories do not predict attention gradients in which more attention is allocated to some things than to others. Spatial awareness data from all four experiments showed that more attention was paid to enemy aircraft that directly threatened the subject than was paid to other aircraft. Experiment 2 showed that the resulting attention gradient steepened as enemy number increased: when attentional demand was increased by increasing the total number of aircraft, subjects seemed to increase the amount of attention paid to direct threats by reallocating attention previously paid to other aircraft. Experiments 3 and 4 provided additional support for the reallocation hypothesis by showing that less attention was paid to individual neutral aircraft when the number of enemy aircraft increased (even though the total number of aircraft had not changed). These data suggest that attention is allocated to objects based on the degree to which they threaten or can assist the subject's task performance.

Author

**N90-28984# Royal Aerospace Establishment, Farnborough (England). Human Factors Div.**

### THE SIMULATION OF LOCALIZED SOUNDS FOR IMPROVED SITUATIONAL AWARENESS

PETER L. N. NAISH /n AGARD, Situational Awareness in Aerospace Operations 9 p Apr. 1990

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It is argued that, in everyday life, the directional information available in sounds is automatically incorporated into the listener's overall awareness of the situation. The absence of such cues in the air-borne environment must inevitably impoverish the data base from which the pilot builds his appreciation of the situation. Experiments are reported, which indicate that modifying cockpit sounds, to give them a synthetic directional quality, would indeed facilitate spatial appreciation.

Author

**N90-28985# School of Aerospace Medicine, Brooks AFB, TX. THE EFFECTS OF ACOUSTIC ORIENTATION CUES ON INSTRUMENT FLIGHT PERFORMANCE IN A FLIGHT SIMULATOR**

TERENCE J. LYONS, KENT K. GILLINGHAM, DON C. TEAS, WILLIAM R. ERCOLINE, and CAROLYN OAKLEY /n AGARD, Situational Awareness in Aerospace Operations 10 p Apr. 1990 Prepared in cooperation with Krug International, Houston, TX Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An initial version of an Acoustic Orientation Instrument (AOI)--in which airspeed was displayed as sound frequency, vertical velocity as amplitude modulation rate, and bank angle as right-left lateralization-- was evaluated in a T-40 (Link GAT-3) motion-based simulator. Fifteen pilots and three non-pilots were taught to use the AOI and flew simulated flight profiles under conditions of neither visual nor auditory instrumentation (NO INPUT), AOI signals only

(AOI), T-40 simulator instrumentation only (VISUAL), and T-40 simulator instrumentation with AOI signals (BOTH). Bank control under AOI conditions was significantly better than under the NO INPUT condition for all flying tasks. Bank control under VISUAL conditions was significantly better than under the AOI condition only during turning and when performing certain complex secondary tasks. The pilots' ability to use the AOI to control vertical velocity and airspeed was less apparent. However, during straight-and-level flight, turns, and descents the AOI provided the pilots with sufficient information to maintain controlled flight. Factors of potential importance in using sound to convey aircraft attitude and motion information are discussed.

Author

**N90-28986# Los Alamos National Lab., NM.**

### WORKLOAD INDUCED SPATIO-TEMPORAL DISTORTIONS AND SAFETY OF FLIGHT: AN INVESTIGATION OF COGNITIVE INTRUSIONS IN PERCEPTUAL PROCESSES

CHRISTOPHER L. BARRETT and SCOTT A. WEISGERBER (Naval Weapons Center, China Lake, CA.) /n AGARD, Situational Awareness in Aerospace Operations 9 p Apr. 1990 Previously announced as N90-14771

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A theoretical analysis of the relationship between cognitive complexity and the perception of time and distance is presented and experimentally verified. Complex tasks produce high rates of mental representation which affect the subjective sense of duration and, through the subjective time scale, the percept of distance derived from dynamic visual cues (i.e., visual cues requiring rate integration). The analysis of the interrelationship of subjective time and subjective distance yields the prediction that, as a function of cognitive complexity, distance estimates derived from dynamic visual cues will be longer than the actual distance whereas estimates based on perceived temporal duration will be shorter than the actual distance. This prediction was confirmed in an experiment in which subjects (both pilots and non-pilots) estimated distances using either temporal cues or dynamic visual cues. The distance estimation task was also combined with secondary loading tasks in order to vary the overall task complexity. The results indicated that distance estimates based on temporal cues were underestimated while estimates based on visual cues were overestimated. This spatio-temporal distortion effect increased with increases in overall task complexity.

Author

**N90-28988# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).**

### TRACKING PERFORMANCE AND INFLUENCE OF FIELD OF VIEW [PERFORMANCE DE TRACKING ET INFLUENCE DU CHAMP DE VISION]

PATRICK SANDOR and ALAIN LEGER /n AGARD, Situational Awareness in Aerospace Operations 7 p Apr. 1990 In FRENCH

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Eyesight with limited field of view becomes habitual with the use of optronic systems mounted on a helmet. In order to evaluate the influence of these devices on operator performance, the effect of several levels of visual restriction on the task of visual-manual tracking and on eye-head coordination, was tested. The performance is moderately reduced when the available field of view is small (20 deg), without improvement in the intermediate field (70 deg). The origin of this reduction must be researched bringing into play the adaptive neuro-sensory mechanisms needed for the limitation of the field rather than the restricted biomechanics imposed by the target motion range. This aspect obeys the analysis of the change of eye-head coordination tied to the string restriction of the field.

Transl. by E.R.

N90-28989# Italian Air Force Aerospace Medical Center, Rome. Neuropsychophysiology Group.

**NEUROPHYSIOLOGICAL CORRELATES OF INFORMATION PROCESSING ABILITIES DURING DIVIDED ATTENTION SITUATIONS IN AIR TRAFFIC CONTROLLERS**

S. PORCU, G. DELLERBA, L. RICCIO, M. PERONTI, and P. VENTURI (La Sapienza Univ., Rome, Italy) In AGARD, Situational Awareness in Aerospace Operations 9 p Apr. 1990

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The relationships that exist between arousal, cognitive functioning and generalized expectancy of control in a group of air traffic controllers (ATC), are studied in conditions of single and dual tasks. Furthermore, under the same conditions and based on performance outcome, evidence was sought of eventual differences in cognitive functioning which could be related to the diversity of professional ATC skills. Data show that arousal is increased in the dual-task: (1) N2 peak latency is positively correlated to arousal in both tasks; (2) correlates inversely with perceived control in the single task; (3) relates inversely with activation in the dual task; and (4) adjusted arousal correlates with perceived control. Finally, N2 peak latency appears to be sensitive to ATC skill.

Author

N90-28990# Paris V Univ. (France). Lab. d'Anthropologie Appliquée.

**LOSS OF ALERTNESS AND CONSCIOUSNESS FROM PILOT POSITION DURING LONG RANGE FLIGHT [BAISSE DE LA VIGILANCE ET CONSCIENCE DE LA SITUATION DES PILOTES AU COURS DE VOLLS LONG-COURRIERS]**

A. COBLENTZ, J.-P. FOUILLOT, R. MOLLARD, and PH. CABON In AGARD, Situational Awareness in Aerospace Operations 9 p Apr. 1990 In FRENCH

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The variations in levels of alertness over the course of monotonous activities have been presented by many authors. In aeronautics, during long flight, these variations in alertness can reduce pilot performance and ability to an appreciable amount. After study of pilot behavior during this type of flight, ground based research was undertaken. The objective was to identify phases of hyperalertness and to evaluate their impact on pilot performance and its effect on consciousness. The method rests on the use of ambulatory techniques such as EEG, EOG, heart rate, and motor function of the pilot during flight, as well as the observation of the task. The first results in the preliminary phase, supported by eight long range flights, are presented.

Transl. by E.R.

N90-28994 Institute for Perception RVO-TNO, Soesterberg (Netherlands). Afd. Verrichtingspsychologie.

**SITUATIONAL AWARENESS AND VESTIBULAR STIMULATION: THE INFLUENCE OF WHOLE-BODY ROTATION UPON TASK PERFORMANCE Final Report**

C. J. E. WIENTJES and W. BLES 14 Aug. 1989 21 p In DUTCH; ENGLISH summary

(Contract A86/KLU/048)

(IZF-1989-14; TD-89-1051; ETN-90-97386) Copyright Avail:

Inst. for Perception RVO-TNO, P.O. Box 23, 3769 ZG

Soesterberg, Netherlands

The effects of vestibular stimulation (whole-body rotation) on performance memory comparison task, subjective well-being and visual perception were investigated. It was found that rotation results in a deterioration of the task performance, in motion sickness and anxiety responses; the visibility of the characters on the display that was used for the presentation of the task was also affected. It is concluded that rotation may result in adverse effects on the information processing, mainly as a consequence of problems with visual perception that seem to be due to insufficient suppression of the vestibular reflex. These findings are important for the problem of situational awareness because similar

reactions may occur with vestibular stimulation in high performance aircrafts.

ESA

N90-28995 Institute for Perception RVO-TNO, Soesterberg (Netherlands). Afd. Verrichtingspsychologie.

**COGNITION VERSUS SENSATION: A PARADIGM FOR REORIENTATION Final Report**

L. C. BOER Jul. 1989 25 p In DUTCH; ENGLISH summary (Contract A85/K/077)

(IZF-1989-20; TD-89-1050; ETN-90-97388) Copyright Avail: Inst. for Perception RVO-TNO, P.O. Box 23, 3769 ZG Soesterberg, Netherlands

The progress in the research project Orientation and Navigation which is, for example, important for (fighter) pilots, is reported. A task of mental orientation is described in which subjects are required to image themselves rotating in the horizontal plane; at the same time they undergo an actual rotation in the same plane but in a different direction. It is found that the imagined reorientation angle has a strong effect on the cognitive processing time; the actual rotation, however, has no effect. Conflicts between actual and imagined orientation are not found. Suggestions for continued investigations are presented.

ESA

N90-28996# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**TECHNIQUES AND APPLICATIONS FOR BINAURAL SOUND MANIPULATION IN HUMAN-MACHINE INTERFACES**

DURAND R. BEGAULT and ELIZABETH M. WENZEL Aug. 1990 27 p Submitted for publication

(NASA-TM-102279; A-90066; NAS 1.15:102279) Avail: NTIS HC A03/MF A01 CSCL 05/9

The implementation of binaural sound to speech and auditory sound cues (auditory icons) is addressed from both an applications and technical standpoint. Techniques overviewed include processing by means of filtering with head-related transfer functions. Application to advanced cockpit human interface systems is discussed, although the techniques are extendable to any human-machine interface. Research issues pertaining to three-dimensional sound displays under investigation at the Aerospace Human Factors Division at NASA Ames Research Center are described.

Author

N90-28997# Air Force Human Resources Lab., Brooks AFB, TX.

**AIR FORCE OFFICER QUALIFYING TEST (AFOQT):**

**DEVELOPMENT OF QUICK SCORE COMPOSITES FOR FORMS P1 AND P2 Interim Technical Report, Nov. 1987 - Jan. 1990**

TODD C. SPERL and MALCOLM JAMES REE Jun. 1990 39 p (AD-A223868; AFHRL-TR-90-3) Avail: NTIS HC A03/MF A01 CSCL 05/8

The purpose of this effort was to develop an instrument to predict success on the Air Force Officer Qualifying Test (AFOQT) Forms P. This device, referred to as Quick Score Composites (QSC), will aid in the identification of individuals likely to pass AFOQT requirement in applying for a commission in the Air Force. The subjects were 6,192 applicants administered AFPQT Forms P1 and P2. Two item selection methods (point-biserial and random) were compared for accuracy, reliability, and control of differential score prediction for gender and ethnic groups. Results showed that QSC scores based on random item selection within subtest are effective predictors of the AFOQT composites. This was indicated by their comparable reliability to that of the other method, high positive correlation with the composites they represent, and introduction of less gender and ethnic bias than that introduced by the point-biserial method.

GRA

N90-28998# Naval Surface Warfare Center, Dahlgren, VA. Strategic Systems Dept.

**SELECTIVE LEARNING ALGORITHM FOR CERTAIN TYPES OF LEARNING FAILURE IN MULTILAYER PERCEPTRONS Final Report**

GEORGE ROGERS and JEFFREY L. SOLKA Jun. 1990 14 p

## 53 BEHAVIORAL SCIENCES

(AD-A223982; NSWC/TR-90-167) Avail: NTIS HC A03/MF A01  
CSCL 05/8

A simple selective learning algorithm for use with Multilayer Perceptrons (MLPs) is presented. This algorithm has proved useful in certain types of problems where learning failure occurs using standard back propagation. Examples of these problems are included. The algorithm is based on the rms output error, computed across all output nodes and all training patterns. The learning rate is decreased for all individual output nodes each time the error is less than a user chosen multiple of the rms error corresponding to the previous pass. This algorithm has produced convergence where the standard fixed gain back propagation failed. GRA

**N90-29773#** Naval Health Research Center, San Diego, CA.  
Operational Performance Dept.

### COPING STRATEGIES AND MOOD DURING COLD WEATHER TRAINING Interim Report

ROSS R. VICKERS, JR., DAVID W. KOLAR, and DENNIS L.

KELLEHER 20 Dec. 1989 19 p

(AD-A223915; NHRC-89-47) Avail: NTIS HC A03/MF A01

CSCL 05/8

Adverse emotional reactions are a recognized problem in cold weather operations. The hypothesis that these reactions are related to coping strategies employed in the cold was tested. The coping strategies and emotional status of men going through winter cold weather training were compared to those of men going through summer mountain warfare training. The men going through cold weather training reported higher levels of depressed mood, anger, and anxiety and lower levels of happiness and activity. These men also reported more frequent thoughts about other times and places as a means of coping. Coping strategies were moderately strong predictors of mood during both the winter and summer training programs, and analyses of covariance controlling for the group differences in coping by escapist thinking showed that this difference could account for the observed group differences in mood. The study confirmed that coping strategies are related to adverse emotional reactions in cold weather settings. Additional research to identify the specific factors in cold weather training that elicit maladaptive coping could help develop programs to foster positive coping. GRA

**N90-29774#** California Univ., Berkeley. Dept. of Psychology.  
NORMS AND PERCEPTION OF EVENTS Annual Technical

Report No 2, 1 Jul. 1989 - 15 Jun. 1990

DANIEL KAHNEMAN 15 Jun. 1990 36 p

(Contract AF-AFOSR-0206-89; AF PROJ. 2313)

(AD-A224236; AFOSR-90-0760TR) Avail: NTIS HC A03/MF A01

CSCL 05/8

A study of contingent coding in normality judgements yielded disappointing results. A systematic exploration was started of the relation between discriminability and similarity, which will be extended to categorization and normality. A series of studies established essentially perfect dimensional independence in object-specific priming. A theoretical and empirical examination was conducted of close counterfactuals. Two separate projects dealt with the process of comparison, continuing and extending work reported last year. GRA

**N90-29775#** New York Univ., New York. Neuromagnetism Lab.  
ATTENTION, IMAGERY, AND MEMORY: A NEUROMAGNETIC INVESTIGATION Annual Technical Report, 1 Mar. 1989 - 28 Feb. 1990

LLOYD KAUFMAN and SAMUEL J. WILLIAMSON 15 May 1990 8 p

(Contract F49620-88-K-0004; AF PROJ. 2313)

(AD-A224560; TR-90-1; AFOSR-90-0779TR) Avail: NTIS HC A02/MF A01 CSCL 05/8

This report describes work on mental imagery, short term memory scanning, language-related mental tasks, and visual attention. In the field of mental imagery it was found that searching memory to determine if or if not a visual form had been seen before, there is a change in the state of the occipital (visual)

cortex. This change is commensurate in time with the reaction time indicating that the mental search is complete. It was also shown that engaging in language related tasks does not have a similar effect on visual cortex, but it does have a similar effect on temporal cortex. Using visually presented words to initiate a mental imaging task results in related changes in activity of visual cortex, and also temporal cortex. However, when the same words are used in rhyming tasks, the major effect is on left temporal cortex. Using acoustically presented words in a similar task produces parallel results, although the effects on visual cortex are not so reliability found across subjects, and both imaging and rhyming affect temporal cortex, suggesting a role for language in imagery. In another memory scanning experiment subjects attempted to determine if a musical note was or was not a member of a set of previously heard notes. The duration of the change in brain state, implied by suppression of alpha band activity, was related to the size of the memory set, provided that it was recorded in a region that picked up activity originating in temporal areas, probably auditory cortex. GRA

**N90-29776#** Minnesota Univ., Minneapolis. Dept. of Psychology.

### ABILITY AND METACOGNITIVE DETERMINANTS OF SKILL ACQUISITION AND TRANSFER Final Report, 1 Jan. 1989 - 30 Apr. 1990

RUTH KANFER and PHILLIP L. ACKERMAN 30 Jun. 1990 91 p

(Contract AF-AFOSR-0242-89; AF PROJ. 2313)

(AD-A224569; AFOSR-90-0783TR) Avail: NTIS HC A05/MF A01 CSCL 05/8

This report reviews a theoretical framework and empirical research concerning the interactions between cognitive abilities (both general intellectual and perceptual speed) and self-regulatory/metacognitive processes (including emotion control and motivation control) during complex skill acquisition. The framework outlines how ability and metacognitive strategies affect attention and cognitive effort as determinants of individual and group differences in task performance during skill acquisition. Specifically, the self-regulatory strategy of emotion control affects task performance early in skill acquisition, when strategy of emotion control affects task performance early in skill acquisition, when attentional resource demands are diminished. Individual differences in general ability interact with the dynamic attentional demands of complex tasks during training, and thus further interact with the influence of these two self-regulatory strategies. Two experiments delineating the interactive effects of training for emotion control and motivation control were conducted, with a criterion air traffic controller simulation task. GRA

**N90-29777\*#** Illinois Univ., Champaign.

### PHYSIOLOGICAL METRICS OF MENTAL WORKLOAD: A REVIEW OF RECENT PROGRESS Interim Report, 1 Jan. - 1 Oct. 1989

ARTHUR F. KRAMER Jun. 1990 58 p Submitted for publication Sponsored in part by Office of Naval Technology, Arlington, VA (Contract NAG2-308)

(NASA-CR-187290; NAS 1.26:187290; AD-A223701; NPPRDC-TN-90-23) Avail: NTIS HC A04/MF A01 CSCL 06/4

This report reviews research on physiological metrics of mental workload performed in the last decade. The focus of the review is on measurement techniques that have potential for fundamental explanation of mental workload and for use in operational environments. The techniques are examined within a framework of measurement criteria. These criteria include: sensitivity, diagnosticity, intrusiveness, reliability, and generality of application. Over 200 articles are covered by the review. Measures reviewed include: electroencephalograms, event-related potentials, magnetoencephalograms, positron emission tomography, electro-oculograms, cardiovascular measures, pupillometry, respiratory measures, and electrodermal measures. GRA

N90-29778# Los Alamos National Lab., NM.

**QTA (QUESTIONNAIRE-TASK-ANALYSIS): AN ELECTRONIC TOOL FOR JOB/TASK ANALYSIS**

F. KAY HOUGHTON and R. JAY FRIES 1990 5 p Presented at the Association for the Development of Computer-based Instruction Systems (ADCIS) Meeting, San Diego, CA, 29 Oct. - 1 Nov. 1990

(Contract W-7405-ENG-36)

(DE90-008944; LA-UR-90-776; CONF-901055-1) Avail: NTIS HC A01/MF A01

When a computer-based training (CBT) package is part of a performance-based training system, a job/task analysis (JTA) to identify and document training requirements is the first step. To identify and document training requirements, performance-based training mandates that a job/task analysis be completed. To simplify the task of performing the job/task analysis for the control room operators at the plutonium facility at Los Alamos National Laboratory, we wrote the MODULA-2 program QUESTIONNAIRE-TASK-ANALYSIS (QTA). Because we were performing the job/task analysis to meet the requirements of DOE Order 5480.18, the programming was based on the documentation presented in the DOE documents Training Accreditation Program Manuals (TAP 1, TAP 2, and TAP 3). The model for the questionnaire portion of the program was Attachment I-8, page I-33, of TAP 2-88. The analysis that recommends no-train, train or overtrain uses the decision tree on page I-10 of TAP 2-88. However, the program is useful beyond just compliance with the Order. The program performs two functions: it collects numerical data from a questionnaire with a rating scale, and it analyzes the data. After the data are collected, the analysis portion uses a decision tree to make training recommendations. The data may be collected using a long form or a short form of the questionnaire. The analysis procedure creates three analysis files based on job classifications of the respondents. Because of the dual capabilities of the program, QTA may be used by a respondent to complete the questionnaire or the analyst to analyze the results of the survey. Before discussing the QTA program in detail, we will briefly review the process of performing a job task analysis.

DOE

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### MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

Includes human engineering; biotechnology; and space suits and protective clothing.

A90-50250

**SELECTED READINGS IN HUMAN FACTORS**

MICHAEL VENTURINO, ED. Santa Monica, CA, Human Factors Society, 1990, 413 p. No individual items are abstracted in this volume.

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Topics in human-factors engineering are discussed in a collection of previously published reviews and reports. Sections are devoted to human-machine systems, information representation and displays, stimulus-response compatibility and motor control, time-sharing and mental workload, skill acquisition and skilled performance, and human-computer interaction. Consideration is given to engineering psychology, control and knowledge systems, airborne displays for flight and navigation, operator loading tasks, part-task training for tracking and manual control, and the formatting of alphanumeric displays.

T.K.

A90-50542\* Duke Univ., Durham, NC.

**EFFECT OF JOINT IMPERFECTIONS ON STATIC CONTROL OF ADAPTIVE STRUCTURES AS SPACE CRANES**

A. V. RAMESH, SENOL UTKU (Duke University, Durham, NC), B. K. WADA, and G. S. CHEN (JPL, Pasadena, CA) Journal of Intelligent Material Systems and Structures (ISSN 1045-389X), vol.

1, July 1990, p. 309-326. refs

(Contract NAS7-100)

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Effect of imperfections in the joints of an adaptive structure on its slow (no inertia forces) motion along a prescribed trajectory as a space crane is studied. Two mathematical models to predict the effect of joint imperfections are proposed. The two models are used to obtain estimates of the deviations of the node of the space crane to which the end-effector is attached, from its prescribed trajectory. An application of the models to a two-section space crane is given.

Author

A90-50702

**ENHANCED ANATOMICALLY REPRESENTATIVE MANIKIN PELVIS SUPPORTING A SELF-CONTAINED INSTRUMENTATION/ELECTRONICS SUBSYSTEM**

PAUL H. FRISCH (Applied Physics, Inc., Nanuet, NY) and PETER AYOUB (U.S. Navy, Naval Air Development Center, Warminster, PA) SAFE Journal, vol. 20, Fall 1990, p. 35-40. refs

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An anatomically based pelvis, incorporating a 96 channel (expandable to 128 channel) analog subsystem, has been developed. It provides the signal conditioning necessary for monitoring manikin biodynamic response and a capability to interface with a processor subsystem. The transfer of the location of the signal conditioning to the pelvis has provided sufficient space in the thorax to reintroduce the chest deformation analysis. The design is compatible with both male/female percentiles and Hybrid III.

B.P.

A90-51079 Veterans Administration Hospital, Palo Alto, CA.

**AN INTERACTIVE GRAPHICS-BASED MODEL OF THE LOWER EXTREMITY TO STUDY ORTHOPAEDIC SURGICAL PROCEDURES**

SCOTT L. DELP, J. PETER LOAN, MELISSA G. HOY, FELIX E. ZAJAC, ERIC L. TOPP (U.S. Veterans Administration, Medical Center, Palo Alto; Stanford University, CA) et al. IEEE Transactions on Biomedical Engineering (ISSN 0018-9294), vol. 37, Aug. 1990, p. 757-767. Research supported by the Department of Veterans Affairs and NASA. refs

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A model of the human lower extremity is developed to study how changes in musculoskeletal geometry and musculotendon parameters affect muscle force and its moment about the joints. The lines of action of 43 musculotendon actuators were defined based on their anatomical relationships to three-dimensional bone-surface representations. A model for each actuator was formulated to compute its isometric force-length relation. The kinematics of the lower extremity were defined by modeling the hip, knee, ankle, subtalar, and metatarsophalangeal joints, so that the force and joint moment of each musculotendon actuator can be computed for any body position. The joint moments calculated with the model compare well with experimentally measured isometric joint moments. A graphical interface to the model has also been developed. It allows the user to visualize the musculoskeletal geometry and to manipulate the model parameters to study the biomechanical consequences of orthopedic surgical procedures.

I.E.

A90-52259

**SEGREGATION OF BASIC COLORS IN AN INFORMATION DISPLAY**

HARVEY S. SMALLMAN and ROBERT M. BOYNTON (California, University, La Jolla) Optical Society of America, Journal, A: Optics and Image Science (ISSN 0740-3232), vol. 7, Oct. 1990, p. 1985-1994. Research supported by 3-M Co. refs

(Contract NIH-EY-01451)

Copyright

The extent to which optimal examples of basic colors segregate in an information display is discussed. To establish an optimal basic color code, an extensive data base of surface-color-naming data was utilized and it was found that the upper limit to efficient color coding can almost be doubled by using focal basic colors.

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However, it appears that what counts for the useful segregation of colors is their separation in color space rather than whether they are optimal basic colors. By first selecting a subset of optimal basic colors and then adding intermediate nonbasic ones, a set of 14 colors was obtained, seven focal basic and seven intermediate ones, all of which segregate well from one another. This set of 14 colors could probably be extended to 18 by adding white, black, brown, and a light gray that contrasts well with the background.

B.P.

**A90-52753**

### CONCEPT OF ADAPTABILITY IN SPACE MODULES

MIGUEL COOPER *Journal of Aerospace Engineering* (ISSN 0893-1321), vol. 3, Oct. 1990, p. 235-240.

Copyright

The space program is aiming towards the permanent use of space; to build and establish an orbital space station, a moon base and depart to Mars and beyond. The need for the total independency from the earth's natural resources and work in the design of a modular space base is emphasized. This modular concept will lead to other space goals as extensions of the primary project. The basic technology has to be defined, then relatively minor adjustments will make it possible to reach new objectives such as a first approach for a lunar base and for a Mars manned mission. This concept aims towards an open technology in which standards and recommendations will be created to assemble huge space bases and spaceships from specific modules that perform certain functions, that in combination will make it possible to reach the status of permanent use and exploration of space. Author

**A90-52946\*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

### REMOTE MISSION SPECIALIST - A STUDY IN REAL-TIME, ADAPTIVE PLANNING

MARK J. ROKEY (JPL, Pasadena, CA) *IEEE Transactions on Robotics and Automation* (ISSN 1042-296X), vol. 6, Aug. 1990, p. 455-461. refs

Copyright

A high-level planning architecture for robotic operations is presented. The remote mission specialist integrates high-level directives with low-level primitives executable by a run-time controller for command of autonomous servicing activities. The planner has been designed to address such issues as adaptive plan generation, real-time performance, and operator intervention.

I.E.

**A90-52997#**

### NEAR-MINIMUM-TIME CONTROL OF A FLEXIBLE MANIPULATOR

J. L. JUNKINS (Texas A & M University, College Station) and N. K. HECHT IN: *AIAA/AAS Astrodynamics Conference*, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 426-430. Research supported by the Texas Advanced Technology Program. refs  
(Contract F49620-87-C-0078)

(AIAA PAPER 90-2916) Copyright

Near-minimum-time control of flexible manipulators can be accomplished by designing a controller that tracks a reference maneuver. The control method presented here uses a near-minimum-time rigid link reference maneuver to generate reference control torques, and a Liapunov controller to make the flexible manipulator track the reference maneuver while reducing and eventually eliminating flexible motions. The near-minimum-time reference maneuver uses a smoothed bang-bang control plus a term to cancel the nonlinear dynamics of the rigid manipulator. The Liapunov function is a weighted sum of the energies of the elements of the flexible manipulator, and the control law is chosen to make the rate of change of the Liapunov function negative. The Liapunov function is bounded during a maneuver, and decays asymptotically after the maneuver ends.

Author

**N90-28979#** Royal Aerospace Establishment, Farnborough (England).

### TOWARDS A FUTURE COCKPIT: THE PROTOTYPING AND PILOT INTEGRATION OF THE MISSION MANAGEMENT AID (MMA)

C. P. GIBSON and A. J. GARRETT (British Aerospace Public Ltd. Co., Kingston-upon-Thames, England) In AGARD, *Situational Awareness in Aerospace Operations* 9 p Apr. 1990

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The Mission Management Aid (MMA) Joint Venture (MMAJV) is a three phase program, the objectives of which are to: (1) establish the functional requirements and feasibility of a device(s) such as the MMA; (2) to prove the techniques for accomplishing this in a rapid prototyping environment and produce a set of functional specifications; and (3) to optimize the MMA functionality and develop the MMI on a real time Mission Capable Simulation (MCS). With the ever increasing trend towards complex integrated avionics systems and the increased level and capability of threat anticipated in future hostile scenarios, the requirement for the pilot of the single seat aircraft to maximize his situational awareness at all times must be one of the prime issues in driving the development of such systems. The requirement is outlined for the MMA and the major functional areas of sensor fusion, situation assessment, dynamic planning and the Man-Machine Interface are introduced. Some of the Human Factors issues associated with the introduction of an intelligent Mission Management Aid (MMA) and the increasing need to promote situational awareness are discussed. Issues relating to the design requirements and evaluation of such systems are also discussed.

Author

**N90-28980#** School of Aerospace Medicine, Brooks AFB, TX. Crew Technology Div.

### THE THREE-DIMENSIONAL STRUCTURE OF VISUAL ATTENTION AND ITS IMPLICATIONS FOR DISPLAY DESIGN

FRED H. PREVIC In AGARD, *Situational Awareness in Aerospace Operations* 7 p Apr. 1990

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The ability to direct attention toward far visual space while maintaining good spatial orientation is imperative for pilots of high performance fighter aircraft. In actuality, this task is quite similar to that performed during such everyday activities as reaching and locomotion. A theoretical analysis of the three-dimensional (3-D) structure of visual attention and its involvement in normal perceptual activities leads to the conclusion that far attention is: (1) biased toward the upper right visual field; (2) associated with saccadic scanning confined to the central 30 degs of the visual field; and (3) primarily utilized in performing local perceptual processes. In properly designed aircraft displays, then, far attention can be encouraged both by restricting local perceptual analyses to certain regions of the visual field, and by enabling attitude control to be performed using more global (ambient) mechanisms.

Author

**N90-28981#** Central Electricity Generating Board, Gloucester (England).

### A REAL TIME EVALUATION OF THE USE OF A PERSPECTIVE FORMAT TO PROMOTE SITUATIONAL AWARENESS IN USERS OF AIR TO AIR TACTICAL DISPLAYS Abstract Only

D. RIDLEY In AGARD, *Situational Awareness in Aerospace Operations* 1 p Apr. 1990

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Networked data systems such as JTIDS (Joint Tactical Information Distribution System) promise a substantial increase in the amount of information available to aircrew involved in air defense. This will include more detailed information regarding relative heights of hostile and friendly airborne units. Such information will be an important factor in BVR (Beyond Visual Range) air defense engagements using missiles such as AMRAAM

(Advanced Medium Range Air to Air Missile). On the basis of psychological theory it was predicted that a perspective display format, would allow a greater volume of situational awareness data to be shown intuitively than would be the case with a conventional plan format. Specifically it should allow information regarding relative height to be more easily comprehended. A real time, cockpit based, air defense simulation was used to compare pilot performance using a perspective situational awareness display with performance with an equivalent plan view display. Twelve subjects were instructed to attack and destroy a constantly evading target aircraft that had to be distinguished from a number of hostile aircraft. Performance measures showed that subjects had more difficulty in learning to use the perspective display. However once they were familiar with this format their results were significantly better than those achieved using the plan display. These results are discussed with reference to requirements for air defense displays in general and networked data displays. Author

**N90-28982#** Human Engineering Labs., Aberdeen Proving Ground, MD.

#### COUNTERAIR SITUATION AWARENESS DISPLAY FOR ARMY AVIATION

CHRISTOPHER C. SMYTH, FRANK J. MALKIN, and WILLIAM B. DEBELLIS /n AGARD, Situational Awareness in Aerospace Operations 10 p. Apr. 1990

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An air combat display concept is proposed for Army aviation helicopter cockpits. The effects of the choice of the display size, the display symbol size, and the area of coverage as a counterair situation awareness display are discussed. The display shows the tracks of aircraft about the host helicopter on a Planar Position Indicator (PPI) graph via the open broadcast radio net of the division-wide air defense radar coverage. The display is used to alert the aircrew to the presence of aircraft in the area and cue to the location of enemy threats for the counterair role. It is concluded that with the relatively small display sizes used in helicopters, an accurate determination of the position of enemy threats during air-to-air combat cannot be made by an aviator from the PPI alone. It must be interactive allowing access to detailed information about a track of interest to be useful. Author

**N90-28983#** Laboratoire de Medecine Aerospatiale, Breitigny-sur-Orge (France).

#### TARGET ACQUISITION UNDER LOAD FACTORS:

#### ADVANTAGES AND DISADVANTAGES OF A HELMET MOUNTED SIGHT [DESIGNATION D'OBJECTIFS SOUS FACTEUR DE CHARGE: INTERET ET LIMITES DU VISEUR DE CASQUE]

A. LEGER and PATRICK SANDOR /n AGARD, Situational Awareness in Aerospace Operations 10 p. Apr. 1990 In FRENCH

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Helmet mounted viewfinders are actually considered as a possible means for improving the consciousness of the situation of combat pilots. The potential advantage of this type of device can depend on the opening up of cramped aircraft interiors, like the +Gz acceleration of air to air combat. An experimental study in a centrifuge was conducted in order to attempt an evaluation of the impact of +Gz acceleration on the designated function of the helmet mounted viewfinder. The results show that up to +5Gz, the reduction of tracking performance under delayed load factor is moderated. These are tied to biomechanical characteristics and functional method of eye-head coordination. Transl. by E.R.

**N90-28999#** Aerospace Medical Research Labs., Wright-Patterson AFB, OH.

#### MILITARY AIRCREW SEATING: A HUMAN FACTORS ENGINEERING APPROACH Summary Report, Dec. 1985 - Dec. 1988 Ph.D. Thesis

JAMES DAVID WHITELEY Dec. 1989 199 p

(Contract AF PROJ. 7231)  
(AD-A218049; AAMRL-TR-89-046) Avail: NTIS HC A09/MF A02 CSCL 23/2

The application of human factors engineering to the realm of aerospace design is not a new or unique concept; however, its direct application to aircrew seat design considerations, human response to whole body vibration, new seat design concepts, and several methods of evaluating and contrasting aircrew seats is a new development. During this effort, two aircrew seats were developed. These primarily consisted of new seat pan and backrest structures. Two distinct experiments were performed. Data was collected to determine pressure distribution on the various seat pans in a static environment. The new seat pans were statistically different (lower maximum pressure) than the current seat pan. The current seat pan averaged almost double new seat pressure readings. The second experiment in which 12 active duty Air Force males participated in a series of dynamic vibration exposure tests which simulated the measurements was accomplished. GRA

**N90-29000\*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

#### PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 1

GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 481 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989

(Contract NAS7-918)

(NASA-CR-186856; JPL-PUBL-89-7-VOL-1; NAS 1.26:186856)  
Avail: NTIS HC A21/MF A03 CSCL 05/8

The theme of the Conference was man-machine collaboration in space. Topics addressed include: redundant manipulators; man-machine systems; telerobot architecture; remote sensing and planning; navigation; neural networks; fundamental AI research; and reasoning under uncertainty.

**N90-29001\*#** Robotics Research Corp., Milford, OH.

#### A 17 DEGREE OF FREEDOM ANTHROPOMORPHIC MANIPULATOR

HAVARD I. VOLD, JAMES P. KARLEN, JACK M. THOMPSON, JR., JAMES D. FARRELL, and PAUL H. EISMANN /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 19-28 31 Jan. 1989

Avail: NTIS HC A21/MF A03 CSCL 05/8

A 17 axis anthropomorphic manipulator, providing coordinated control of two seven degree of freedom arms mounted on a three degree of freedom torso-waist assembly, is presented. This massively redundant telerobot, designated the Robotics Research K/B-2017 Dexterous Manipulator, employs a modular mechanism design with joint-mounted actuators based on brushless motors and harmonic drive gear reducers. Direct joint torque control at the servo level causes these high-output joint drives to behave like direct-drive actuators, facilitating the implementation of an effective impedance control scheme. The redundant, but conservative motion control system models the manipulator as a spring-loaded linkage with viscous damping and rotary inertia at each joint. This approach allows for real time, sensor-driven control of manipulator pose using a hierarchy of competing rules, or objective functions, to avoid unplanned collisions with objects in the workplace, to produce energy-efficient, graceful motion, to increase leverage, to control effective impedance at the tool or to favor overloaded joints. Author

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#### A NEW APPROACH TO GLOBAL CONTROL OF REDUNDANT MANIPULATORS

HOMAYOUN SERAJI /n its Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 29-38 31 Jan. 1989  
Avail: NTIS HC A21/MF A03 CSCL 05/8

A new and simple approach to configuration control of redundant manipulators is presented. In this approach, the redundancy is utilized to control the manipulator configuration

directly in task space, where the task will be performed. A number of kinematic functions are defined to reflect the desirable configuration that will be achieved for a given end-effector position. The user-defined kinematic functions and the end-effector Cartesian coordinates are combined to form a set of task-related configuration variables as generalized coordinates for the manipulator. An adaptive scheme is then utilized to globally control the configuration variables so as to achieve tracking of some desired reference trajectories. This accomplishes the basic task of desired end-effector motion, while utilizing the redundancy to achieve any additional task through the desired time variation of the kinematic functions. The control law is simple and computationally very fast, and does not require the complex manipulator dynamic model.

Author

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**KINEMATIC FUNCTIONS FOR THE 7 DOF ROBOTICS RESEARCH ARM**

K. KREUTZ, M. LONG, and HOMAYOUN SERAJI *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 39-48 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

The Robotics Research Model K-1207 manipulator is a redundant 7R serial link arm with offsets at all joints. To uniquely determine joint angles for a given end-effector configuration, the redundancy is parameterized by a scalar variable which corresponds to the angle between the manipulator elbow plane and the vertical plane. The forward kinematic mappings from joint-space to end-effector configuration and elbow angle, and the augmented Jacobian matrix which gives end-effector and elbow angle rates as a function of joint rates, are also derived.

Author

N90-29004\*# New Mexico State Univ., Las Cruces.

**CARTESIAN CONTROL OF REDUNDANT ROBOTS**

R. COLBAUGH and K. GLASS *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 49-58 31 Jan. 1989 Sponsored in part by Sandia Labs.*

Avail: NTIS HC A21/MF A03 CSCL 05/8

A Cartesian-space position/force controller is presented for redundant robots. The proposed control structure partitions the control problem into a nonredundant position/force trajectory tracking problem and a redundant mapping problem between Cartesian control input F is a set member of the set R(<sup>sup</sup> m) and robot actuator torque T is a set member of the set R(<sup>sup</sup> n) (for redundant robots, m is less than n). The underdetermined nature of the F yields T map is exploited so that the robot redundancy is utilized to improve the dynamic response of the robot. This dynamically optimal F yields T map is implemented locally (in time) so that it is computationally efficient for on-line control; however, it is shown that the map possesses globally optimal characteristics. Additionally, it is demonstrated that the dynamically optimal F yields T map can be modified so that the robot redundancy is used to simultaneously improve the dynamic response and realize any specified kinematic performance objective (e.g., manipulability maximization or obstacle avoidance). Computer simulation results are given for a four degree of freedom planar redundant robot under Cartesian control, and demonstrate that position/force trajectory tracking and effective redundancy utilization can be achieved simultaneously with the proposed controller.

Author

N90-29005\*# Ford Aerospace and Communications Corp., Palo Alto, CA. Space Systems Div.

**KINEMATICS, CONTROLS, AND PATH PLANNING RESULTS FOR A REDUNDANT MANIPULATOR**

BRUCE GRETZ and SCOTT W. TILLEY *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 59-68 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

The inverse kinematics solution, a modal position control algorithm, and path planning results for a 7 degree of freedom

manipulator are presented. The redundant arm consists of two links with shoulder and elbow joints and a spherical wrist. The inverse kinematics problem for tip position is solved and the redundant joint is identified. It is also shown that a locus of tip positions exists in which there are kinematic limitations on self-motion. A computationally simple modal position control algorithm has been developed which guarantees a nearly constant closed-loop dynamic response throughout the workspace. If all closed-loop poles are assigned to the same location, the algorithm can be implemented with very little computation. To further reduce the required computation, the modal gains are updated only at discrete time intervals. Criteria are developed for the frequency of these updates. For commanding manipulator movements, a 5th-order spline which minimizes jerk provides a smooth tip-space path. Schemes for deriving a corresponding joint-space trajectory are discussed. Modifying the trajectory to avoid joint torque saturation when a tip payload is added is also considered. Simulation results are presented.

Author

N90-29006\*# Toronto Univ. (Ontario). Robotics and Automation Lab.

**A COMPLETE ANALYTICAL SOLUTION FOR THE INVERSE INSTANTANEOUS KINEMATICS OF A SPHERICAL-REVOLUTE-SPHERICAL (7R) REDUNDANT MANIPULATOR**

R. P. PODHORODESKI, R. G. FENTON, and A. A. GOLDENBERG *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 69-78 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

Using a method based upon resolving joint velocities using reciprocal screw quantities, compact analytical expressions are generated for the inverse solution of the joint rates of a seven revolute (spherical-revolute-spherical) manipulator. The method uses a sequential decomposition of screw coordinates to identify reciprocal screw quantities used in the resolution of a particular joint rate solution, and also to identify a Jacobian null-space basis used for the direct solution of optimal joint rates. The results of the screw decomposition are used to study special configurations of the manipulator, generating expressions for the inverse velocity solution for all non-singular configurations of the manipulator, and identifying singular configurations and their characteristics. Two functions are therefore served: a new general method for the solution of the inverse velocity problem is presented; and complete analytical expressions are derived for the resolution of the joint rates of a seven degree of freedom manipulator useful for telerobotic and industrial robotic application.

Author

N90-29007\*# Massachusetts Inst. of Tech., Cambridge. Man-Machine Systems Lab.

**ADJUSTABLE IMPEDANCE, FORCE FEEDBACK AND COMMAND LANGUAGE AIDS FOR TELEROBOTICS (PARTS 1-4 OF AN 8-PART MIT PROGRESS REPORT)**

THOMAS B. SHERIDAN, G. JAGGANATH RAJU, FORREST T. BUZAN, WAEL YARED, and JONG PARK *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 81-88 31 Jan. 1989 Sponsored in part by NASA, Ames Research Center*

Avail: NTIS HC A21/MF A03 CSCL 05/8

Projects recently completed or in progress at MIT Man-Machine Systems Laboratory are summarized. (1) A 2-part impedance network model of a single degree of freedom remote manipulation system is presented in which a human operator at the master port interacts with a task object at the slave port in a remote location is presented. (2) The extension of the predictor concept to include force feedback and dynamic modeling of the manipulator and the environment is addressed. (3) A system was constructed to infer intent from the operator's commands and the teleoperation context, and generalize this information to interpret future commands. (4) A command language system is being designed that is robust, easy to learn, and has more natural man-machine communication. A general telerobot problem selected as an

important command language context is finding a collision-free path for a robot. Author

**N90-29008\***# Massachusetts Inst. of Tech., Cambridge.  
**VARIABLE FORCE AND VISUAL FEEDBACK EFFECTS ON TELEOPERATOR MAN/MACHINE PERFORMANCE**  
MICHAEL J. MASSIMINO and THOMAS B. SHERIDAN *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 89-98 31 Jan. 1989  
Avail: NTIS HC A21/MF A03 CSCL 05/8

An experimental study was conducted to determine the effects of various forms of visual and force feedback on human performance for several telemanipulation tasks. Experiments were conducted with varying frame rates and subtended visual angles, with and without force feedback. Author

**N90-29009\***# Wisconsin Univ., Madison. Dept. of Industrial Engineering.

**TELEOPERATOR COMFORT AND PSYCHOMETRIC STABILITY: CRITERIA FOR LIMITING MASTER-CONTROLLER FORCES OF OPERATION AND FEEDBACK DURING TELEMANIPULATION**

STEVEN F. WIKER, ELAINE HERSHKOWITZ, and JOHN ZIK *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 99-107 31 Jan. 1989  
Avail: NTIS HC A21/MF A03 CSCL 05/8

The following question is addressed: How much force should operators exert, or experience, when operating a telemanipulator master-controller for sustained periods without encountering significant fatigue and discomfort, and without loss of stability in psychometric perception of force. The need to minimize exertion demands to avoid fatigue is diametrically opposed by the need to present a wide range of force stimuli to enhance perception of applied or reflected forces. For 104 minutes subjects repetitiously performed a series of 15 s isometric pinch grasps; controlled at 5, 15, and 25 percent of their maximum voluntary strength. Cyclic pinch grasps were separated by rest intervals of 7.5 and 15 s. Upon completion of every 10 minute period, subjects interrupted grasping activities to gage the intensity of fatigue and discomfort in the hand and forearm using a cross-modal matching technique. A series of psychometric tests were then conducted to determine accuracy and stability in the subject's perception of force experienced. Results showed that onset of sensations of discomfort and fatigue were dependent upon the magnitude of grasp force, work/rest ratio, and progression of task. Declines in force magnitude estimation slopes, indicating a reduction in force perception sensitivity, occurred with increased grasp force when work/rest ratios were greater than 1.0. Specific recommendations for avoiding discomfort and shifts in force perception, by limiting pinch grasp force required for master-controller operation and range of force reflection or work/rest ratios, are provided. Author

**N90-29010\***# Center for Engineering Applications, Memphis, TN.

**MEASUREMENT OF HAND DYNAMICS IN A MICROSURGERY ENVIRONMENT: PRELIMINARY DATA IN THE DESIGN OF A BIMANUAL TELEMICRO-OPERATION TEST BED**

STEVE CHARLES and ROY WILLIAMS *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 109-118 31 Jan. 1989  
Avail: NTIS HC A21/MF A03 CSCL 05/8

Data describing the microsurgeon's hand dynamics was recorded and analyzed in order to provide an accurate model for the telemicrosurgery application of the Bimanual Telemicro-operation Test Bed. The model, in turn, will guide the development of algorithms for the control of robotic systems in bimanual telemicro-operation tasks. Measurements were made at the hand-tool interface and include position, acceleration and force between the tool-finger interface. Position information was captured using an orthogonal pulsed magnetic field positioning system resulting in measurements in all six degrees-of-freedom (DOF). Acceleration data at the hands was obtained using accelerometers positioned in a triaxial arrangement on the back of the hand allowing

measurements in all three cartesian-coordinate axes. Force data was obtained by using miniature load cells positioned between the tool and the finger and included those forces experienced perpendicular to the tool shaft and those transferred from the tool-tissue site. Position data will provide a minimum/maximum reference frame for the robotic system's work space or envelope. Acceleration data will define the response times needed by the robotic system in order to emulate and subsequently outperform the human operator's tool movements. The force measurements will aid in designing a force-reflective, force-scaling system as well as defining the range of forces the robotic system will encounter. All analog data was acquired by a 16-channel analog-to-digital conversion system residing in a IBM PC/AT-compatible computer at the Center's laboratory. The same system was also used to analyze and present the data. Author

**N90-29011\***# Bureau of Mines, Pittsburgh, PA.  
**HUMAN FACTORS MODEL CONCERNING THE MAN-MACHINE INTERFACE OF MINING CREWSTATIONS**

JAMES P. RIDER and RICHARD L. UNGER *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 119-127 31 Jan. 1989  
Avail: NTIS HC A21/MF A03 CSCL 05/8

The U.S. Bureau of Mines is developing a computer model to analyze the human factors aspect of mining machine operator compartments. The model will be used as a research tool and as a design aid. It will have the capability to perform the following: simulated anthropometric or reach assessment, visibility analysis, illumination analysis, structural analysis of the protective canopy, operator fatigue analysis, and computation of an ingress-egress rating. The model will make extensive use of graphics to simplify data input and output. Two dimensional orthographic projections of the machine and its operator compartment are digitized and the data rebuilt into a three dimensional representation of the mining machine. Anthropometric data from either an individual or any size population may be used. The model is intended for use by equipment manufacturers and mining companies during initial design work on new machines. In addition to its use in machine design, the model should prove helpful as an accident investigation tool and for determining the effects of machine modifications made in the field on the critical areas of visibility and control reach ability. Author

**N90-29012\***# British Aerospace Public Ltd. Co., Bristol (England). Sowerby Research Centre.

**DEVELOPMENT OF A FLEXIBLE TEST-BED FOR ROBOTICS, TELEMANIPULATION AND SERVICING RESEARCH**

BARRY F. DAVIES *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 129-138 31 Jan. 1989  
Avail: NTIS HC A21/MF A03 CSCL 05/8

The development of a flexible operation test-bed, based around a commercially available ASEA industrial robot is described. The test-bed was designed to investigate fundamental human factors issues concerned with the unique problems of robotic manipulation in the hostile environment of Space. Author

**N90-29013\***# Dortmund Univ. (Germany, F.R.). Inst. of Robotics Research.

**CONTROL OF INTELLIGENT ROBOTS IN SPACE**

E. FREUND and CH. BUEHLER *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 141-150 31 Jan. 1989 Sponsored in part by Bundesminister fuer Forschung und Technologie, Federal Republic of Germany  
Avail: NTIS HC A21/MF A03 CSCL 05/8

In view of space activities like International Space Station, Man-Tended-Free-Flyer (MTFF) and free flying platforms, the development of intelligent robotic systems is gaining increasing importance. The range of applications that have to be performed by robotic systems in space includes e.g., the execution of experiments in space laboratories, the service and maintenance of satellites and flying platforms, the support of automatic

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production processes or the assembly of large network structures. Some of these tasks will require the development of bi-armed or of multiple robotic systems including functional redundancy. For the development of robotic systems which are able to perform this variety of tasks a hierarchically structured modular concept of automation is required. This concept is characterized by high flexibility as well as by automatic specialization to the particular sequence of tasks that have to be performed. On the other hand it has to be designed such that the human operator can influence or guide the system on different levels of control supervision, and decision. This leads to requirements for the hardware and software concept which permit a range of application of the robotic systems from telemanipulation to autonomous operation. The realization of this goal requires strong efforts in the development of new methods, software and hardware concepts, and the integration into an automation concept.

Author

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### MODULARITY IN ROBOTIC SYSTEMS

DELBERT TESAR and MICHAEL S. BUTLER *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 151-162 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

Most robotic systems today are designed one at a time, at a high cost of time and money. This wasteful approach has been necessary because the industry has not established a foundation for the continued evolution of intelligent machines. The next generation of robots will have to be generic, versatile machines capable of absorbing new technology rapidly and economically. This approach is demonstrated in the success of the personal computer, which can be upgraded or expanded with new software and hardware at virtually every level. Modularity is perceived as a major opportunity to reduce the 6 to 7 year design cycle time now required for new robotic manipulators, greatly increasing the breadth and speed of diffusion of robotic systems in manufacturing. Modularity and its crucial role in the next generation of intelligent machines are the focus of interest. The main advantages that modularity provides are examined; types of modules needed to create a generic robot are discussed. Structural modules designed by the robotics group at the University of Texas at Austin are examined to demonstrate the advantages of modular design.

Author

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### A SYSTEM ARCHITECTURE FOR A PLANETARY ROVER

D. B. SMITH and J. R. MATIJEVIC *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 163-184 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

Each planetary mission requires a complex space vehicle which integrates several functions to accomplish the mission and science objectives. A Mars Rover is one of these vehicles, and extends the normal spacecraft functionality with two additional functions: surface mobility and sample acquisition. All functions are assembled into a hierarchical and structured format to understand the complexities of interactions between functions during different mission times. It can graphically show data flow between functions, and most importantly, the necessary control flow to avoid unambiguous results. Diagrams are presented organizing the functions into a structured, block format where each block represents a major function at the system level. As such, there are six blocks representing telecomm, power, thermal, science, mobility and sampling under a supervisory block called Data Management/Executive. Each block is a simple collection of state machines arranged into a hierarchical order very close to the NASREM model for Telerobotics. Each layer within a block represents a level of control for a set of state machines that do the three primary interface functions: command, telemetry, and fault protection. This latter function is expanded to include automatic reactions to the environment as well as internal faults. Lastly, diagrams are presented that trace the system operations

involved in moving from site to site after site selection. The diagrams clearly illustrate both the data and control flows. They also illustrate inter-block data transfers and a hierarchical approach to fault protection. This systems architecture can be used to determine functional requirements, interface specifications and be used as a mechanism for grouping subsystems (i.e., collecting groups of machines, or blocks consistent with good and testable implementations).

Author

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### THE NASA/OAST TELEROBOT TESTBED ARCHITECTURE

J. R. MATIJEVIC, W. F. ZIMMERMAN, and S. DOLINSKY *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 185-195 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

Through a phased development such as a laboratory-based research testbed, the NASA/OAST Telerobot Testbed provides an environment for system test and demonstration of the technology which will usefully complement, significantly enhance, or even replace manned space activities. By integrating advanced sensing, robotic manipulation and intelligent control under human-interactive supervision, the Testbed will ultimately demonstrate execution of a variety of generic tasks suggestive of space assembly, maintenance, repair, and telescience. The Testbed system features a hierarchical layered control structure compatible with the incorporation of evolving technologies as they become available. The Testbed system is physically implemented in a computing architecture which allows for ease of integration of these technologies while preserving the flexibility for test of a variety of man-machine modes. The development currently in progress on the functional and implementation architectures of the NASA/OAST Testbed and capabilities planned for the coming years are presented.

Author

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### FORMULATION OF DESIGN GUIDELINES FOR AUTOMATED ROBOTIC ASSEMBLY IN OUTERSPACE

SUREN N. DWIVEDI, GARY JONES, S. BANERJEE, and S. SRIVASTAVA (Bowie State Univ., MD.) *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 197-206 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

The approach for arriving at design guidelines for assembly by robots in outer space is illustrated. The use of robots in a zero gravity environment necessitates that extra factors over and above normal design guidelines be taken into account. Besides, many of the guidelines for assembly by robots on earth do not apply in space. However, considering the axioms for normal design and assembly as one set, guidelines for design and robotic assembly as another, and guidelines for design and assembly in space as the third set, unions and intersections of these sets can generate guidelines for two or more of these conditions taken together - say design and manual assembly in space. Therein lies the potential to develop expert systems in the future, which would use an exhaustive database and similar guidelines to arrive at those required by a superposition of these conditions.

Author

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### AUTOMATION AND ROBOTICS TECHNOLOGY FOR INTELLIGENT MINING SYSTEMS

JEFFREY H. WELSH *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 207-216 31 Jan. 1989*

Avail: NTIS HC A21/MF A03 CSCL 05/8

The U.S. Bureau of Mines is approaching the problems of accidents and efficiency in the mining industry through the application of automation and robotics to mining systems. This technology can increase safety by removing workers from hazardous areas of the mines or from performing hazardous tasks. The short-term goal of the Automation and Robotics program is to develop technology that can be implemented in the form of an

autonomous mining machine using current continuous mining machine equipment. In the longer term, the goal is to conduct research that will lead to new intelligent mining systems that capitalize on the capabilities of robotics. The Bureau of Mines Automation and Robotics program has been structured to produce the technology required for the short- and long-term goals. The short-term goal of application of automation and robotics to an existing mining machine, resulting in autonomous operation, is expected to be accomplished within five years. Key technology elements required for an autonomous continuous mining machine are well underway and include machine navigation systems, coal-rock interface detectors, machine condition monitoring, and intelligent computer systems. The Bureau of Mines program is described, including status of key technology elements for an autonomous continuous mining machine, the program schedule, and future work. Although the program is directed toward underground mining, much of the technology being developed may have applications for space systems or mining on the Moon or other planets.

Author

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**A FAST LIGHTSTRIPE RANGEFINDING SYSTEM WITH SMART VLSI SENSOR**

ANDREW GRUSS, L. RICHARD CARLEY, and TAKEO KANADE  
*In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 219-228 31 Jan. 1989

Avail: NTIS HC A21/MF A03 CSCL 05/8

The focus of the research is to build a compact, high performance lightstripe rangefinder using a Very Large Scale Integration (VLSI) smart photosensor array. Rangefinding, the measurement of the three-dimensional profile of an object or scene, is a critical component for many robotic applications, and therefore many techniques were developed. Of these, lightstripe rangefinding is one of the most widely used and reliable techniques available. Though practical, the speed of sampling range data by the conventional light stripe technique is severely limited. A conventional light stripe rangefinder operates in a step-and-repeat manner. A stripe source is projected on an object, a video image is acquired, range data is extracted from the image, the stripe is stepped, and the process repeats. Range acquisition is limited by the time needed to grab the video images, increasing linearly with the desired horizontal resolution. During the acquisition of a range image, the objects in the scene being scanned must be stationary. Thus, the long scene sampling time of step-and-repeat rangefinders limits their application. The fast range sensor proposed is based on the modification of this basic lightstripe ranging technique in a manner described by Sato and Kida. This technique does not require a sampling of images at various stripe positions to build a range map. Rather, an entire range image is acquired in parallel while the stripe source is swept continuously across the scene. Total time to acquire the range image data is independent of the range map resolution. The target rangefinding system will acquire 1,000 100 x 100 point range images per second with 0.5 percent range accuracy. It will be compact and rugged enough to be mounted on the end effector of a robot arm to aid in object manipulation and assembly tasks.

Author

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**METHODS AND STRATEGIES OF OBJECT LOCALIZATION**

LEJUN SHAO and RICHARD A. VOLZ (Texas A&M Univ., College Station.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 229-239 31 Jan. 1989

Avail: NTIS HC A21/MF A03 CSCL 05/8

An important property of an intelligent robot is to be able to determine the location of an object in 3-D space. A general object localization system structure is proposed, some important issues on localization discussed, and an overview given for current available object localization algorithms and systems. The algorithms reviewed are characterized by their feature extracting and matching

strategies; the range finding methods; the types of locatable objects; and the mathematical formulating methods.

Author

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**A LASER TRACKING DYNAMIC ROBOT METROLOGY INSTRUMENT**

G. A. PARKER and J. R. R. MAYER *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 241-250 31 Jan. 1989 Sponsored in part by Bureau of Community Reference, Commission of the European Community, Brussels; and Department of Trade and Industry, England

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Research work over several years has resulted in the development of a laser tracking instrument capable of dynamic 3-D measurements of robot end-effector trajectories. The instrument characteristics and experiments to measure the static and dynamic performance of a robot in an industrial manufacturing environment are described. The use of this technology for space applications is examined.

Author

**N90-29022\*#** Maryland Univ., College Park. Computer Vision Lab.

**ROBOT ACTING ON MOVING BODIES (RAMBO): INTERACTION WITH TUMBLING OBJECTS**

LARRY S. DAVIS, DANIEL DEMENTHON, THOR BESTUL, SOTIRIOS ZIAVRAS, H. V. SRINIVASAN, MADHU SIDDALINGAIAH, and DAVID HARWOOD *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 251-260 31 Jan. 1989 (Contract DACA-76-88-C-0008)

Avail: NTIS HC A21/MF A03 CSCL 05/8

Interaction with tumbling objects will become more common as human activities in space expand. Attempting to interact with a large complex object translating and rotating in space, a human operator using only his visual and mental capacities may not be able to estimate the object motion, plan actions or control those actions. A robot system (RAMBO) equipped with a camera, which, given a sequence of simple tasks, can perform these tasks on a tumbling object, is being developed. RAMBO is given a complete geometric model of the object. A low level vision module extracts and groups characteristic features in images of the object. The positions of the object are determined in a sequence of images, and a motion estimate of the object is obtained. This motion estimate is used to plan trajectories of the robot tool to relative locations nearby the object sufficient for achieving the tasks. More specifically, low level vision uses parallel algorithms for image enhancement by symmetric nearest neighbor filtering, edge detection by local gradient operators, and corner extraction by sector filtering. The object pose estimation is a Hough transform method accumulating position hypotheses obtained by matching triples of image features (corners) to triples of model features. To maximize computing speed, the estimate of the position in space of a triple of features is obtained by decomposing its perspective view into a product of rotations and a scaled orthographic projection. This allows use of 2-D lookup tables at each stage of the decomposition. The position hypotheses for each possible match of model feature triples and image feature triples are calculated in parallel. Trajectory planning combines heuristic and dynamic programming techniques. Then trajectories are created using dynamic interpolations between initial and goal trajectories. All the parallel algorithms run on a Connection Machine CM-2 with 16K processors.

Author

**N90-29023\*#** Carnegie-Mellon Univ., Pittsburgh, PA. Dept. of Electrical and Computer Engineering.

**REAL-TIME EDGE TRACKING USING A TACTILE SENSOR**

ALAN D. BERGER, RICHARD VOLPE, and PRADEEP K. KHOSLA *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 261-271 31 Jan. 1989

Avail: NTIS HC A21/MF A03 CSCL 05/8

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Object recognition through the use of input from multiple sensors is an important aspect of an autonomous manipulation system. In tactile object recognition, it is necessary to determine the location and orientation of object edges and surfaces. A controller is proposed that utilizes a tactile sensor in the feedback loop of a manipulator to track along edges. In the control system, the data from the tactile sensor is first processed to find edges. The parameters of these edges are then used to generate a control signal to a hybrid controller. Theory is presented for tactile edge detection and an edge tracking controller. In addition, experimental verification of the edge tracking controller is presented. Author

**N90-29024\***# Rensselaer Polytechnic Inst., Troy, NY. Dept. of Electrical, Computer, and Systems Engineering.

### PLANNING 3-D COLLISION-FREE PATHS USING SPHERES

SUSAN BONNER and ROBERT B. KELLEY *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 273-282 31 Jan. 1989

Avail: NTIS HC A21/MF A03 CSCL 05/8

A scheme for the representation of objects, the Successive Spherical Approximation (SSA), facilitates the rapid planning of collision-free paths in a 3-D, dynamic environment. The hierarchical nature of the SSA allows collision-free paths to be determined efficiently while still providing for the exact representation of dynamic objects. The concept of a freespace cell is introduced to allow human 3-D conceptual knowledge to be used in facilitating satisfying choices for paths. Collisions can be detected at a rate better than 1 second per environment object per path. This speed enables the path planning process to apply a hierarchy of rules to create a heuristically satisfying collision-free path. Author

**N90-29036\***# Bolt, Beranek, and Newman, Inc., Cambridge, MA.

### PLAN RECOGNITION FOR SPACE TELEROBOTICS

BRADLEY A. GOODMAN and DIANE J. LITMAN (Bell Telephone Labs., Inc., Murray Hill, NJ.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 395-404 31 Jan. 1989

(Contract NSF IRI-87-01874)

Avail: NTIS HC A21/MF A03 CSCL 05/8

Current research on space telerobots has largely focused on two problem areas: executing remotely controlled actions (the tele part of telerobotics) or planning to execute them (the robot part). This work has largely ignored one of the key aspects of telerobots: the interaction between the machine and its operator. For this interaction to be felicitous, the machine must successfully understand what the operator is trying to accomplish with particular remote-controlled actions. Only with the understanding of the operator's purpose for performing these actions can the robot intelligently assist the operator, perhaps by warning of possible errors or taking over part of the task. There is a need for such an understanding in the telerobotics domain and an intelligent interface being developed in the chemical process design domain addresses the same issues. Author

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### CAUSAL SIMULATION AND SENSOR PLANNING IN PREDICTIVE MONITORING

RICHARD J. DOYLE *In* its Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 405-414 31 Jan. 1989

Avail: NTIS HC A21/MF A03 CSCL 05/8

Two issues are addressed which arise in the task of detecting anomalous behavior in complex systems with numerous sensor channels: how to adjust alarm thresholds dynamically, within the changing operating context of the system, and how to utilize sensors selectively, so that nominal operation can be verified reliably without processing a prohibitive amount of sensor data. The approach involves simulation of a causal model of the system, which provides information on expected sensor values, and on dependencies between predicted events, useful in assessing the relative importance of events so that sensor resources can be

allocated effectively. The potential applicability of this work to the execution monitoring of robot task plans is briefly discussed.

Author

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### PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 2

GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 393 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989

(Contract NAS7-918)

(NASA-CR-186857; JPL-PUBL-89-7-VOL-2; NAS 1.26:186857)

Avail: NTIS HC A17/MF A03 CSCL 05/8

These proceedings contain papers presented at the NASA Conference on Space Telerobotics held in Pasadena, January 31 to February 2, 1989. The theme of the Conference was man-machine collaboration in space. The Conference provided a forum for researchers and engineers to exchange ideas on the research and development required for application of telerobotics technology to the space systems planned for the 1990s and beyond. The Conference: (1) provided a view of current NASA telerobotic research and development; (2) stimulated technical exchange on man-machine systems, manipulator control, machine sensing, machine intelligence, concurrent computation, and system architectures; and (3) identified important unsolved problems of current interest which can be dealt with by future research.

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### CHARACTERIZATION AND CONTROL OF SELF-MOTIONS IN REDUNDANT MANIPULATORS

J. BURDICK (California Inst. of Tech., Pasadena.) and HOMAYOUN SERAJI *In* its Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 3-14 31 Jan. 1989 Sponsored in part by System Development Foundation

Avail: NTIS HC A17/MF A03 CSCL 05/8

The presence of redundant degrees of freedom in a manipulator structure leads to a physical phenomenon known as a self-motion, which is a continuous motion of the manipulator joints that leaves the end-effector motionless. In the first part of the paper, a global manifold mapping reformulation of manipulator kinematics is reviewed, and the inverse kinematic solution for redundant manipulators is developed in terms of self-motion manifolds. Global characterizations of the self-motion manifolds in terms of their number, geometry, homotopy class, and null space are reviewed using examples. Much previous work in redundant manipulator control has been concerned with the redundancy resolution problem, in which methods are developed to determine, or resolve, the motion of the joints in order to achieve end-effector trajectory control while optimizing additional objective functions. Redundancy resolution problems can be equivalently posed as the control of self-motions. Alternatives for redundancy resolution are briefly discussed.

Author

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### MULTIPLE COOPERATING MANIPULATORS: THE CASE OF KINEMATICALLY REDUNDANT ARMS

IAN D. WALKER, ROBERT A. FREEMAN, and STEVEN I. MARCUS *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 15-24 31 Jan. 1989 Sponsored in part by Bureau of Engineering Research

(Contract F49620-86-C-0045; AF-AFOSR-0029-86; NSF ECS-86-17860)

Avail: NTIS HC A17/MF A03 CSCL 05/8

Existing work concerning two or more manipulators simultaneously grasping and transferring a common load is continued and extended. Specifically considered is the case of one or more arms being kinematically redundant. Some existing results in the modeling and control of single redundant arms and multiple manipulators are reviewed. The cooperating situation is

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modeled in terms of a set of coordinates representing object motion and internal object squeezing. Nominal trajectories in these coordinates are produced via actuator load distribution algorithms introduced previously. A controller is developed to track these desired object trajectories while making use of the kinematic redundancy to additionally aid the cooperation and coordination of the system. It is shown how the existence of kinematic redundancy within the system may be used to enhance the degree of cooperation achievable.

Author

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### REFLEXIVE OBSTACLE AVOIDANCE FOR KINEMATICALLY-REDUNDANT MANIPULATORS

JAMES P. KARLEN, JACK M. THOMPSON, JR., JAMES D. FARRELL, and HAVARD I. VOLD *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 25-37 31 Jan. 1989 Sponsored by NASA, Langley Research Center

Avail: NTIS HC A17/MF A03 CSCL 05/8

Dexterous telerobots incorporating 17 or more degrees of freedom operating under coordinated, sensor-driven computer control will play important roles in future space operations. They will also be used on Earth in assignments like fire fighting, construction and battlefield support. A real time, reflexive obstacle avoidance system, seen as a functional requirement for such massively redundant manipulators, was developed using arm-mounted proximity sensors to control manipulator pose. The project involved a review and analysis of alternative proximity sensor technologies for space applications, the development of a general-purpose algorithm for synthesizing sensor inputs, and the implementation of a prototypical system for demonstration and testing. A 7 degree of freedom Robotics Research K-2107HR manipulator was outfitted with ultrasonic proximity sensors as a testbed, and Robotics Research's standard redundant motion control algorithm was modified such that an object detected by sensor arrays located at the elbow effectively applies a force to the manipulator elbow, normal to the axis. The arm is repelled by objects detected by the sensors, causing the robot to steer around objects in the workspace automatically while continuing to move its tool along the commanded path without interruption. The mathematical approach formulated for synthesizing sensor inputs can be employed for redundant robots of any kinematic configuration.

Author

N90-29048\*# McGill Univ., Montreal (Quebec). Research Center for Intelligent Machines.

### PRELIMINARY STUDY OF A SERIAL-PARALLEL REDUNDANT MANIPULATOR

VINCENT HAYWARD and RONALD KURTZ *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 39-48 31 Jan. 1989 Sponsored in part by Natural Sciences and Engineering Research Council, Canada and Fonds pour la Formation des Chercheurs et l'Aide à la Recherche, Quebec

Avail: NTIS HC A17/MF A03 CSCL 05/8

The manipulator design discussed here results from the examination of some of the reasons why redundancy is necessary in general purpose manipulation systems. A spherical joint design actuated in-parallel, having the many advantages of parallel actuation, is described. In addition, the benefits of using redundant actuators are discussed and illustrated in the design by the elimination of loci of singularities from the usable workspace with the addition of only one actuator. Finally, what is known by the authors about space robotics requirements is summarized and the relevance of the proposed design matched against these requirements. The design problems outlined here are viewed as much from the mechanical engineering aspect as from concerns arising from the control and the programming of manipulators.

Author

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### THE JPL TELEROBOT OPERATOR CONTROL STATION. PART 1: HARDWARE

EDWIN P. KAN, JOHN T. TOWER, GEORGE W. HUNKA, and GLENN J. VANSANT (General Electric Co., Moorestown, NJ.) *In* its Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 51-62 31 Jan. 1989

Avail: NTIS HC A17/MF A03 CSCL 05/8

The Operator Control Station of the Jet Propulsion Laboratory (JPL)/NASA Telerobot Demonstrator System provides the man-machine interface between the operator and the system. It provides all the hardware and software for accepting human input for the direct and indirect (supervised) manipulation of the robot arms and tools for task execution. Hardware and software are also provided for the display and feedback of information and control data for the operator's consumption and interaction with the task being executed. The hardware design, system architecture, and its integration and interface with the rest of the Telerobot Demonstrator System are discussed.

Author

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### THE JPL TELEROBOT OPERATOR CONTROL STATION. PART 2: SOFTWARE

EDWIN P. KAN, B. PATRICK LANDELL, SHELDON OXENBERG, and CARL MORIMOTO (General Electric Co., San Jose, CA.) *In* its Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 63-73 31 Jan. 1989

Avail: NTIS HC A17/MF A03 CSCL 05/8

The Operator Control Station of the Jet Propulsion Laboratory (JPL)/NASA Telerobot Demonstrator System provides the man-machine interface between the operator and the system. It provides all the hardware and software for accepting human input for the direct and indirect (supervised) manipulation of the robot arms and tools for task execution. Hardware and software are also provided for the display and feedback of information and control data for the operator's consumption and interaction with the task being executed. The software design of the operator control system is discussed.

Author

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**DESIGN OF A MONITOR AND SIMULATION TERMINAL (MASTER) FOR SPACE STATION TELEROBOTICS AND TELESCIENCE**

L. LOPEZ, C. KONKEL, P. HARMON (System Dynamics, Inc., Huntsville, AL.), and S. KING *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 75-86 31 Jan. 1989

Avail: NTIS HC A17/MF A03 CSCL 05/8

Based on Space Station and planetary spacecraft communication time delays and bandwidth limitations, it will be necessary to develop an intelligent, general purpose ground monitor terminal capable of sophisticated data display and control of on-orbit facilities and remote spacecraft. The basic elements that make up a Monitor and Simulation Terminal (MASTER) include computer overlay video, data compression, forward simulation, mission resource optimization and high level robotic control. Hardware and software elements of a MASTER are being assembled for testbed use. Applications of Neural Networks (NNs) to some key functions of a MASTER are also discussed. These functions are overlay graphics adjustment, object correlation and kinematic-dynamic characterization of the manipulator.

Author

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### PERFORMANCE EVALUATION OF A 6 AXIS HIGH FIDELITY GENERALIZED FORCE REFLECTING TELEOPERATOR

BLAKE HANNAFORD and LAURIE WOOD *In* its Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 87-96 31 Jan. 1989

Avail: NTIS HC A17/MF A03 CSCL 05/8

A few of the results of a major study of over 100 hours of

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experimental teleoperation are presented. Force and torque data recorded from the robot wrist is a rich source of information on the performance of tasks. Performance measures can be computed for whole tasks, or for specific task segments. As a general principle, the performance increases as manipulation capability is increased although the effects may depend on task and performance measure. This study has laid the groundwork for much future work. Further reports will detail additional results which could not be presented here due to lack of space as well as follow-on experiments investigating manipulation under time delay and shared control conditions.

Author

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### IMPLEMENTATION AND DESIGN OF A TELEOPERATION SYSTEM BASED ON A VMEBUS/68020 PIPELINED ARCHITECTURE

THOMAS S. LEE *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 97-107 31 Jan. 1989*

Avail: NTIS HC A17/MF A03 CSCL 05/8

A pipelined control design and architecture for a force-feedback teleoperation system that is being implemented at the Jet Propulsion Laboratory and which will be integrated with the autonomous portion of the testbed to achieve share control is described. At the local site, the operator sees real-time force/torque displays and moves two 6-degree of freedom (dof) force-reflecting hand-controllers as his hands feel the contact force/torques generated at the remote site where the robots interact with the environment. He also uses a graphical user menu to monitor robot states and specify system options. The teleoperation software is written in the C language and runs on MC68020-based processor boards in the VME chassis, which utilizes a real-time operating system; the hardware is configured to realize a four-stage pipeline configuration. The environment is very flexible, such that the system can easily be configured as a stand-alone facility for performing independent research in human factors, force control, and time-delayed systems.

Author

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### HUMAN MACHINE INTERACTION VIA THE TRANSFER OF POWER AND INFORMATION SIGNALS

H. KAZEROONI, W. K. FOSLIEN, B. J. ANDERSON, and T. M. HESSBURG *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 109-119 31 Jan. 1989*

Avail: NTIS HC A17/MF A03 CSCL 05/8

Robot manipulators are designed to perform tasks which would otherwise be executed by a human operator. No manipulator can even approach the speed and accuracy with which humans execute these tasks. But manipulators have the capability to exceed human ability in one particular area: strength. Through any reasonable observation and experience, the human's ability to perform a variety of physical tasks is limited not by his intelligence, but by his physical strength. If, in the appropriate environment, we can more closely integrate the mechanical power of a machine with intellectually driven human hand under the supervisory control of the human's intellect, we will then have a system which is superior to a loosely-integrated combination of a human and his fully automated robot as in the present day robotic systems. We must therefore develop a fundamental approach to the problem of this extending human mechanical power in certain environments. Extenders will be a class of robots worn by humans to increase human mechanical ability, while the wearer's intellect remains the central intelligent control system for manipulating the extender. The human body, in physical contact with the extender, exchanges information signals and power with the extender. Commands are transferred to the extender via the contact forces between the wearer and the extender as opposed to use of joystick (master arm), push-button or key-board to execute such commands that were used in previous man amplifiers. Instead, the operator becomes an integral part of the extender while executing the task. In this unique configuration the mechanical power transfer between the human and extender

occurs in addition to information signal transfer. When the wearer uses the extender to touch and manipulate an object, the extender transfers to the wearer's hand, in feedback fashion, a scaled-down value of the actual external load which the extender is manipulating. This natural feedback force on the wearer's hand allows him to feel the scaled-down value of the external forces in the manipulations. Extenders can be utilized to maneuver very heavy loads in factories, shipyards, airports, and construction sites. In some instances, for example, extenders can replace forklifts. The experimental results for a prototype extender are discussed.

Author

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### TRAJECTORY GENERATION OF SPACE TELEROBOTS

R. LUMIA and A. J. WAVERING *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 123-131 31 Jan. 1989*

Avail: NTIS HC A17/MF A03 CSCL 05/8

The purpose is to review a variety of trajectory generation techniques which may be applied to space telerobots and to identify problems which need to be addressed in future telerobot motion control systems. As a starting point for the development of motion generation systems for space telerobots, the operation and limitations of traditional path-oriented trajectory generation approaches are discussed. This discussion leads to a description of more advanced techniques which have been demonstrated in research laboratories, and their potential applicability to space telerobots. Examples of this work include systems that incorporate sensory-interactive motion capability and optimal motion planning. Additional considerations which need to be addressed for motion control of a space telerobot are described, such as redundancy resolution and the description and generation of constrained and multi-armed cooperative motions. A task decomposition module for a hierarchical telerobot control system which will serve as a testbed for trajectory generation approaches which address these issues is also discussed briefly.

Author

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### ON THE SIMULATION OF SPACE BASED MANIPULATORS WITH CONTACT

MICHAEL W. WALKER and JOSEPH DIONISE *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 133-142 31 Jan. 1989 Sponsored in part by ERIM*

Avail: NTIS HC A17/MF A03 CSCL 05/8

An efficient method of simulating the motion of space based manipulators is presented. Since the manipulators will come into contact with different objects in their environment while carrying out different tasks, an important part of the simulation is the modeling of those contacts. An inverse dynamics controller is used to control a two armed manipulator whose task is to grasp an object floating in space. Simulation results are presented and an evaluation is made of the performance of the controller.

Author

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### PRELIMINARY RESULTS ON NONCOLLOCATED TORQUE CONTROL OF SPACE ROBOT ACTUATORS

SCOTT W. TILLEY, COLIN M. FRANCIS, KEN EMERICK, and MICHAEL G. HOLLARS *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 143-152 31 Jan. 1989*

Avail: NTIS HC A17/MF A03 CSCL 05/8

In the Space Station era, more operations will be performed robotically in space in the areas of servicing, assembly, and experiment tending among others. These robots may have various sets of requirements for accuracy, speed, and force generation, but there will be design constraints such as size, mass, and power dissipation limits. For actuation, a leading motor candidate is a dc brushless type, and there are numerous potential drive trains each with its own advantages and disadvantages. This experiment uses

a harmonic drive and addresses some inherent limitations, namely its backdriveability and low frequency structural resonances. These effects are controlled and diminished by instrumenting the actuator system with a torque transducer on the output shaft. This noncollocated loop is closed to ensure that the commanded torque is accurately delivered to the manipulator link. The actuator system is modelled and its essential parameters identified. The nonlinear model for simulations will include inertias, gearing, stiction, flexibility, and the effects of output load variations. A linear model is extracted and used for designing the noncollocated torque and position feedback loops. These loops are simulated with the structural frequency encountered in the testbed system. Simulation results are given for various commands in position. The use of torque feedback is demonstrated to yield superior performance in settling time and positioning accuracy. An experimental setup being finished consists of a bench mounted motor and harmonic drive actuator system. A torque transducer and two position encoders, each with sufficient resolution and bandwidth, will provide sensory information. Parameters of the physical system are being identified and matched to analytical predictions. Initial feedback control laws will be incorporated in the bench test equipment and various experiments run to validate the designs. The status of these experiments is given.

Author

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**PORTABLE DEXTROUS FORCE FEEDBACK MASTER FOR ROBOT TELEMANIPULATION (PDMFF)**

GRIGORE C. BURDEA and THOMAS H. SPEETER (Bell Telephone Labs., Inc., Holmdel, NJ.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 153-161 31 Jan. 1989 Sponsored in part by Bell Telephone Labs., Inc.

Avail: NTIS HC A17/MF A03 CSCL 05/8

A major drawback of open loop masters is a lack of force feedback, limiting their ability to perform complex tasks such as assembly and repair. Researchers present a simple dexterous force feedback master for computer assisted telemanipulation. The device is compact, portable and can be held in the operator hand, without the need for a special joystick or console. The system is capable of both position feed forward and force feedback, using electronic position sensors and a pneumatic micro-actuator. The level of forces exercised by the pneumatic actuator is such that near rigidity may be attained. Experimental results showing good system linearity and small time lag are given.

Author

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**EXPERIENCES WITH THE JPL TELEROBOT TESTBED: ISSUES AND INSIGHTS**

HENRY W. STONE, BOB BALARAM, and JOHN BEAHAN *In its* Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 163-172 31 Jan. 1989

Avail: NTIS HC A17/MF A03 CSCL 05/8

The Jet Propulsion Laboratory's (JPL) Telerobot Testbed is an integrated robotic testbed used to develop, implement, and evaluate the performance of advanced concepts in autonomous, tele-autonomous, and tele-operated control of robotic manipulators. Using the Telerobot Testbed, researchers demonstrated several of the capabilities and technological advances in the control and integration of robotic systems which have been under development at JPL for several years. In particular, the Telerobot Testbed was recently employed to perform a near completely automated, end-to-end, satellite grapple and repair sequence. The task of integrating existing as well as new concepts in robot control into the Telerobot Testbed has been a very difficult and timely one. Now that researchers have completed the first major milestone (i.e., the end-to-end demonstration) it is important to reflect back upon experiences and to collect the knowledge that has been gained so that improvements can be made to the existing system. It is also believed that the experiences are of value to the others in the robotics community. Therefore, the primary objective here will be to use the Telerobot Testbed as a case study to identify

real problems and technological gaps which exist in the areas of robotics and in particular systems integration. Such problems have surely hindered the development of what could be reasonably called an intelligent robot. In addition to identifying such problems, researchers briefly discuss what approaches have been taken to resolve them or, in several cases, to circumvent them until better approaches can be developed.

Author

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**THE KALI MULTI-ARM ROBOT PROGRAMMING AND CONTROL ENVIRONMENT**

PAUL BACKES, SAMAD HAYATI, VINCENT HAYWARD (McGill Univ., Montreal, Quebec ), and KAM TSO *In its* Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 173-182 31 Jan. 1989

Avail: NTIS HC A17/MF A03 CSCL 05/8

The KALI distributed robot programming and control environment is described within the context of its use in the Jet Propulsion Laboratory (JPL) telerobot project. The purpose of KALI is to provide a flexible robot programming and control environment for coordinated multi-arm robots. Flexibility, both in hardware configuration and software, is desired so that it can be easily modified to test various concepts in robot programming and control, e.g., multi-arm control, force control, sensor integration, teleoperation, and shared control. In the programming environment, user programs written in the C programming language describe trajectories for multiple coordinated manipulators with the aid of KALI function libraries. A system of multiple coordinated manipulators is considered within the programming environment as one motion system. The user plans the trajectory of one controlled Cartesian frame associated with a motion system and describes the positions of the manipulators with respect to that frame. Smooth Cartesian trajectories are achieved through a blending of successive path segments. The manipulator and load dynamics are considered during trajectory generation so that given interface force limits are not exceeded.

Author

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**HOW DO ROBOTS TAKE TWO PARTS APART**

RUZENA K. BAJCSY and CONSTANTINE J. TSIKOS *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 185-195 31 Jan. 1989 Sponsored in part by DEC Systems Research Center, Palo Alto, CA; IBM; Lord Corp., Erie, PA; and North Atlantic Treaty Organization

(Contract NAG5-1045; F49620-85-K-0018; ONR-SB-35923-0; NCGS-1-RO-1-23636-01; N00014-88-K-0632; DAAG29-84-K-0061; NSF DCR-82-19196; NSF INT-85-14199; NSF DMC-85-17315; NS-10939-11)

Avail: NTIS HC A17/MF A03 CSCL 05/8

This research is a natural progression of efforts which begun with the introduction of a new research paradigm in machine perception, called Active Perception. There it was stated that Active Perception is a problem of intelligent control strategies applied to data acquisition processes which will depend on the current state of the data interpretation, including recognition. The disassembly/assembly problem is treated as an Active Perception problem, and a method for autonomous disassembly based on this framework is presented.

Author

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**PERCEPTUAL TELEROBOTICS**

PANOS A. LIGOMENIDES *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 211-220 31 Jan. 1989 Prepared in cooperation with Caelum Research Corp., Silver Spring, MD

Avail: NTIS HC A17/MF A03 CSCL 05/8

A sensory world modeling system, congruent with a human expert's perception, is proposed. The Experiential Knowledge Base (EKB) system can provide a highly intelligible communication

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interface for telemonitoring and telecontrol of a real time robotic system operating in space. Paradigmatic acquisition of empirical perceptual knowledge, and real time experiential pattern recognition and knowledge integration are reviewed. The cellular architecture and operation of the EKB system are also examined. Author

**N90-29065\***# Oak Ridge National Lab., TN. Robotics and Intelligent Systems Program.

### **HERMIES-3: A STEP TOWARD AUTONOMOUS MOBILITY, MANIPULATION, AND PERCEPTION**

C. R. WEISBIN, B. L. BURKS, J. R. EINSTEIN, R. R. FEEZELL, W. W. MANGES, and D. H. THOMPSON /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 233-245 31 Jan. 1989 Previously announced as N89-17249

Avail: NTIS HC A17/MF A03 CSCL 05/8

HERMIES-III is an autonomous robot comprised of a seven degree-of-freedom (DOF) manipulator designed for human scale tasks, a laser range finder, a sonar array, an omni-directional wheel-driven chassis, multiple cameras, and a dual computer system containing a 16-node hypercube expandable to 128 nodes. The current experimental program involves performance of human-scale tasks (e.g., valve manipulation, use of tools), integration of a dexterous manipulator and platform motion in geometrically complex environments, and effective use of multiple cooperating robots (HERMIES-IIB and HERMIES-III). The environment in which the robots operate has been designed to include multiple valves, pipes, meters, obstacles on the floor, valves occluded from view, and multiple paths of differing navigation complexity. The ongoing research program supports the development of autonomous capability for HERMIES-IIB and III to perform complex navigation and manipulation under time constraints, while dealing with imprecise sensory information.

Author

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**HELICOPTER AIRCREW HELMETS AND HEAD INJURY: A PROTECTIVE EFFECT Final Report, Jan. - May 1990**  
JOHN STEPHEN CROWLEY 1 Jun. 1990 9 p  
(AD-A223024; USASC-TR-90-1) Avail: NTIS HC A02/MF A01 CSCL 01/2

The effectiveness of the Army's SPH-4 flight helmet in reducing the severity of head injuries sustained during helicopter accidents was evaluated, using the accident data base at the U.S. Army Safety Center (USASC), Fort Rucker, Alabama. Analysis was restricted to severe (Class A) 1972 to 1988 accidents that were at least partially survivable, using USASC criteria. Occupants who were not wearing a protective helmet were significantly more likely to sustain severe and fatal head injuries than occupants wearing the SPH-4 (RR=3.8 and 6.3, respectively). Unhelmeted non-cockpit occupants faced higher risks (RR=5.3 and 7.5). All personnel regularly participating in helicopter flight, civilian or military, should be equipped with protective headgear.

GRA

**N90-29081\***# Lawrence Livermore National Lab., CA. Systems and Human Performance.

### **HUMAN FACTORS EVALUATION AND VALIDATION CRITERIA FOR QUALITY TRAINING PROGRAMS: DEVELOPMENT, PRESENTATION, AND ASSESSMENT**

WILLIAM W. BANKS 15 May 1990 96 p  
(Contract W-7405-ENG-48)

(DE90-014724; UCRL-ID-103792) Avail: NTIS HC A05/MF A01

This paper provides LLNL managers with a rigorous and quantitative human factors method for assessing the development and validity of any training program at the Lab. A secondary purpose is to provide a checklist for course developers and evaluators. The checklist is easy to use and comprehensive, and it helps ensure that critical components of a training program are adequately addressed.

DOE

**N90-29082** Institute for Perception RVO-TNO, Soesterberg (Netherlands).

### **PROPRIOCEPTION IN AIRCRAFT CONTROL Final Report**

R. N. H. W. VANGENT 12 Oct. 1989 35 p In DUTCH; ENGLISH summary Sponsored by National Defense Research, The Hague, Netherlands (IZF-1989-43; TD-89-4143; ETN-90-97397) Copyright Avail: Inst. for Perception RVO-TNO, P.O. Box 23, 3769 ZG Soesterberg, Netherlands

It was investigated whether with an active stick to feed back a flight variable through proprioception, the visual attention of the pilot for secondary tasks diminishes in a steering task with a remotely piloted vehicle. An experiment was set up in which a remotely piloted vehicle was simulated on a computer and in which the independent factors stick type (active versus passive), task speed, replication and the presence of a visual secondary task were introduced. The results show that with the control of remotely piloted vehicles in the vertical plane proprioceptive feedback of the vertical speed enhances the accuracy of the steering task and the score on the visual secondary task.

ESA

**N90-29083\***# National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA.

### **AUTOMATED SIMULATION AS PART OF A DESIGN WORKSTATION**

ELIZABETH CANTWELL, T. SHENK, P. ROBINSON, and R. UPADHYE (Lawrence Livermore National Lab., CA.) Aug. 1990 15 p Presented at the 20th Intersociety Conference on Environmental Systems, Williamsburg, VA, 9-12 Jul. 1990 (NASA-TM-102852; A-90245; NAS 1.15:102852) Avail: NTIS HC A03/MF A01 CSCL 05/8

A development project for a design workstation for advanced life-support systems (called the DAWN Project, for Design Assistant Workstation), incorporating qualitative simulation, required the implementation of a useful qualitative simulation capability and the integration of qualitative and quantitative simulation such that simulation capabilities are maximized without duplication. The reason is that to produce design solutions to a system goal, the behavior of the system in both a steady and perturbed state must be represented. The Qualitative Simulation Tool (QST), on an expert-system-like model building and simulation interface toll called ScratchPad (SP), and on the integration of QST and SP with more conventional, commercially available simulation packages now being applied in the evaluation of life-support system processes and components are discussed.

Author

**N90-29084\***# Perkin-Elmer Corp., Pomona, CA. Applied Science Operation.

### **ATMOSPHERE AND WATER QUALITY MONITORING ON SPACE STATION FREEDOM**

WILLIAM NIU 1990 22 p Presented at the Space Conference, Long Beach, CA, 22 Sep. 1990 (Contract NAS8-50000)  
(NASA-CR-186707; NAS 1.26:186707) Avail: NTIS HC A03/MF A01 CSCL 06/11

In Space Station Freedom air and water will be supplied in closed loop systems. The monitoring of air and water qualities will ensure the crew health for the long mission duration. The Atmosphere Composition Monitor consists of the following major instruments: (1) a single focusing mass spectrometer to monitor major air constituents and control the oxygen/nitrogen addition for the Space Station; (2) a gas chromatograph/mass spectrometer to detect trace contaminants; (3) a non-dispersive infrared spectrometer to determine carbon monoxide concentration; and (4) a laser particle counter for measuring particulates in the air. An overview of the design and development concepts for the air and water quality monitors is presented.

Author

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### **A HUMAN FACTORS ENGINEERING APPROACH TO THE DEVELOPMENT AND DYNAMIC EVALUATION OF A PROTOTYPE AIRCREW SEAT FOR MILITARY AIRCRAFT**

Ph.D. Thesis - Texas A&M College

JAMES DAVID WHITELEY Dec. 1988 228 p

## 54 MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

(AD-A218283; AFIT/CI/CIA-89-008) Avail: NTIS HC A11/MF A02 CSCL 05/8

The results are presented of an investigation which contrasted the currently available C-130 aircrew seat with two custom made prototype modified C-130 aircrew seats. Twelve active duty AF males participated in a series of dynamic vibration exposure tests which simulated the actual flying environment. Performance tasks, subjective surveys, spinal creep measurements, and seat pain pressure measurements were accomplished. Analysis of variance were performed on data collected. Both buttock and thigh discomfort proved to be statistically responsive to seat type. In each instance, the current seat was rated as causing far more pain and discomfort than the other seats.

Author

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### PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 3

GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 541 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989

(Contract NAS7-918)

(NASA-CR-186858; JPL-PUBL-89-7-VOL-3; NAS 1.26:186858)

Avail: NTIS HC A23/MF A04 CSCL 05/8

The theme of the Conference was man-machine collaboration in space. The Conference provided a forum for researchers and engineers to exchange ideas on the research and development required for application of telerobotics technology to the space systems planned for the 1990s and beyond. The Conference: (1) provided a view of current NASA telerobotic research and development; (2) stimulated technical exchange on man-machine systems, manipulator control, machine sensing, machine intelligence, concurrent computation, and system architectures; and (3) identified important unsolved problems of current interest which can be dealt with by future research.

N90-29781\*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

### THE FLIGHT TELEROBOTIC SERVICER: NASA'S FIRST OPERATIONAL SPACE ROBOT

CHARLES F. FUECHSEL /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 3-7 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

Alternatives to the exploration of Mars by direct human presence are under consideration by both the United States and the Soviet Union. In these concepts, autonomous surface vehicles would navigate the planet performing a variety of detailed exploratory functions such as mapping, seismic measurements, sample collection and analysis. Both of these approaches to the exploration of Mars depend to a high degree on the ability of robotic machinery to perform complex functions without real time human direction. Closer to home and in time, robotics will begin to play a role in space operations in the construction and maintenance of Space Station Freedom. The Flight Telerobotic Servicer Project is introduced as an element of the Space Station Freedom, and its objectives and some special challenges it faces are discussed.

Author

N90-29782\*# Georgia Inst. of Tech., Atlanta. School of Mechanical Engineering.

### MODELING, DESIGN, AND CONTROL OF FLEXIBLE MANIPULATOR ARMS: STATUS AND TRENDS

WAYNE J. BOOK /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 11-24 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

The desire for higher performance manipulators has lead to dynamic behavior in which the flexibility is an essential aspect. The mathematical representations commonly used in modeling flexible arms and arms with flexible drives are examined first. Then design considerations directly arising from the flexible nature

of the arm are discussed. Finally, controls of joints for general and tip motion are discussed.

Author

N90-29783\*# Lockheed Engineering and Sciences Co., Houston, TX.

### DYNAMICAL MODELING OF SERIAL MANIPULATORS WITH FLEXIBLE LINKS AND JOINTS USING THE METHOD OF KINEMATIC INFLUENCE

PHILIP L. GRAVES /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 25-34 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

A method of formulating the dynamical equations of a flexible, serial manipulator is presented, using the Method of Kinematic Influence. The resulting equations account for rigid body motion, structural motion due to link and joint flexibilities, and the coupling between these two motions. Nonlinear inertial loads are included in the equations. A finite order mode summation method is used to model flexibilities. The structural data may be obtained from experimental, finite element, or analytical methods. Nonlinear flexibilities may be included in the model.

Author

N90-29784\*# Toshiba Corp., Kawasaki (Japan).

### CAPTURE OF FREE-FLYING PAYLOADS WITH FLEXIBLE SPACE MANIPULATORS

T. KOMATSU, M. UENOHARA, S. IIKURA, H. MIURA, and I. SHIMOYAMA (Tokyo Univ., Japan) /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 35-44 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

A recently developed control system for capturing free-flying payloads with flexible manipulators is discussed. Three essential points in this control system are, calculating optimal path, using a vision sensor for an external sensor, and controlling active vibration. Experimental results are shown using a planar flexible manipulator.

Author

N90-29785\*# Georgia Inst. of Tech., Atlanta. School of Mechanical Engineering.

### TECHNOLOGY AND TASK PARAMETERS RELATING TO THE EFFECTIVENESS OF THE BRACING STRATEGY

WAYNE J. BOOK and J. J. WANG /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 45-58 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

The bracing strategy has been proposed in various forms as a way to improve robot performance. One version of the strategy employs independent stages of motion. The first stage, referred to as the large or bracing arm, carries the second stage of motion. After the first stage has completed its motion it is braced to provide a more rigid base of motion with a more accurate relationship to the parts to be manipulated. The hypothesis is that more rapid completion of certain tasks is possible with lighter arms using the bracing strategy. While it is easy to make conceptual arguments why this should be so, it is less easy to specify even approximately when this will be true for some reasonably generic situation. There is no relevant experience base with bracing arms to be compared to non-bracing arms. Furthermore, if one were interested in obtaining such practical experience, there would be no methodical guidance on the selection of an interesting case, one in which the unproven approach, bracing, can show its superiority. If one such case exists, only the extent of applicability of the new approach is in question. One set of interesting cases is likely to be applications in which a large workspace must be covered, but where a series of small accurate moves will remain within a smaller region of the total workspace. A prototype application with these characteristics is set up and a skeleton design of arms using the competing strategies are compared.

Author

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### MANIPULATORS WITH FLEXIBLE LINKS: A SIMPLE MODEL AND EXPERIMENTS

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ISAO SHIMOYAMA and IRVING J. OPPENHEIM (Carnegie-Mellon Univ., Pittsburgh, PA.) /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 59-68 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

A simple dynamic model proposed for flexible links is briefly reviewed and experimental control results are presented for different flexible systems. A simple dynamic model is useful for rapid prototyping of manipulators and their control systems, for possible application to manipulator design decisions, and for real time computation as might be applied in model based or feedforward control. Such a model is proposed, with the further advantage that clear physical arguments and explanations can be associated with its simplifying features and with its resulting analytical properties. The model is mathematically equivalent to Rayleigh's method. Taking the example of planar bending, the approach originates in its choice of two amplitude variables, typically chosen as the link end rotations referenced to the chord (or the tangent) motion of the link. This particular choice is key in establishing the advantageous features of the model, and it was used to support the series of experiments reported. Author

N90-29787\*# Ohio State Univ., Columbus. Dept. of Electrical Engineering.

### EXPERIMENTS IN IDENTIFICATION AND CONTROL OF FLEXIBLE-LINK MANIPULATORS

STEPHEN YURKOVICH, ANTHONY P. TZES, and FERNANDO E. PACHECO /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 69-78 31 Jan. 1989

(Contract NAG1-720)

Avail: NTIS HC A23/MF A04 CSCL 05/8

Interest in the study of flexible-link manipulators for space-based applications has risen strongly in recent years. Moreover, numerous experimental results have appeared for the various problems in the modeling, identification and control of such systems. Nevertheless, relatively little literature has appeared involving laboratory verification of tuning controllers for certain types of realistic flexible-link manipulators. Specifically flexible-link manipulators which are required to maintain endpoint accuracy while manipulating loads that are possibly unknown and varying as they undergo disturbance effects from the environment and workspace. Endpoint position control of flexible-link manipulators in these areas are discussed, with laboratory setups consisting of one and two-link manipulators. Author

N90-29788\*# University of Southern California, Los Angeles. Dept. of Computer Science.

### AUTONOMOUS DEXTEROUS END-EFFECTORS FOR SPACE ROBOTICS

GEORGE A. BEKEY, THEA IBERALL, and HUAN LIU /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 81-88 31 Jan. 1989

(Contract JPL-956501; NSF DMC-87-19579; NSF IRI-87-96249)

Avail: NTIS HC A23/MF A04 CSCL 05/8

The development of a knowledge-based controller is summarized for the Belgrade/USC robot hand, a five-fingered end effector, designed for maximum autonomy. The biological principles of the hand and its architecture are presented. The conceptual and software aspects of the grasp selection system are discussed, including both the effects of the geometry of the target object and the task to be performed. Some current research issues are presented. Author

N90-29789\*# Louvain Univ. (Belgium). Dept. of Mechanical Engineering.

### DESIGN AND CONTROL OF A MULTI-FINGERED ROBOT HAND PROVIDED WITH TACTILE FEEDBACK

H. VANBRUSSEL, B. SANTOSO, and D. REYNAERTS /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 89-101 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

The design, construction, control and application of a three

fingered robot hand with nine degrees of freedom and built-in multi-component force sensors is described. The adopted gripper kinematics are justified and optimized with respect to grasping and manipulation flexibility. The hand was constructed with miniature motor drive systems imbedded into the fingers. The control is hierarchically structured and is implemented on a simple PC-AT computer. The hand's dexterity and intelligence are demonstrated with some experiments. E.R.

N90-29791\*# Louvain Univ. (Belgium). Dept. of Mechanical Engineering.

### FORCE/TORQUE AND TACTILE SENSORS FOR SENSOR-BASED MANIPULATOR CONTROL

H. VANBRUSSEL, H. BELIEEN, and CHAO-YING BAO /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 117-128 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

The autonomy of manipulators, in space and in industrial environments, can be dramatically enhanced by the use of force/torque and tactile sensors. The development and future use of a six-component force/torque sensor for the Hermes Robot Arm (HERA) Basic End-Effecter (BEE) is discussed. Then a multifunctional gripper system based on tactile sensors is described. The basic transducing element of the sensor is a sheet of pressure-sensitive polymer. Tactile image processing algorithms for slip detection, object position estimation, and object recognition are described. Author

N90-29792\*# Politecnico di Milano (Italy). Dept. of Mechanics.

### REDUNDANT SENSORIZED ARM+HAND SYSTEM FOR SPACE TELEROBOTIZED MANIPULATION

ALBERTO ROVETTA and PAOLO CAVESTRO /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 129-134 31 Jan. 1989 Sponsored in part by the Italian Educational Ministry

Avail: NTIS HC A23/MF A04 CSCL 05/8

An integrated system, composed of an arm, a wrist, and a mechanical multifingered hand is treated. The hand is on development for possible application in telemanipulation, and is realized in separate parts. The redundancy of the degrees of freedom of the system, the sensors, the application of logical rules, and the supervision of teleoperators may be applied in order to have an optimum of reliability of the system in space telemanipulations. E.R.

N90-29793\*# ST Systems Corp., Lanham, MD.

### IMPEDANCE HAND CONTROLLERS FOR INCREASING EFFICIENCY IN TELEOPERATIONS

C. CARIGNAN and J. TARRANT /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 135-144 31 Jan. 1989 Previously announced as N89-26393

(Contract NAS5-28561)

Avail: NTIS HC A23/MF A04 CSCL 05/8

An impedance hand controller with direct force feedback is examined as an alternative to bilateral force reflection in teleoperations involving force contact. Experimentation revealed an operator preference for direct force feedback which provided a better feel of contact with the environment. The advantages of variable arm impedance were also made clear in tracking tests where subjects preferred the larger hand controller inertias made possible by the acceleration feedback loop in the master arm. The ability to decouple the hand controller impedance from the slave arm dynamics is expected to be even more significant when the inertial properties of various payloads in the slave arm are considered. Author

N90-29794\*# Michigan Univ., Ann Arbor. Dept. of Electrical Engineering and Computer Science.

### TELE-AUTONOMOUS SYSTEMS: NEW METHODS FOR PROJECTING AND COORDINATING INTELLIGENT ACTION AT A DISTANCE

LYNN CONWAY, RICHARD VOLZ (Texas A&M Univ., College

Station.), and MICHAEL W. WALKER /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 147-157 31 Jan. 1989 Sponsored in part by Research Excellence Fund, State of Michigan Avail: NTIS HC A23/MF A04 CSCL 05/8

There is a growing need for humans to perform complex remote operations and to extend the intelligence and experience of experts to distant applications. It is asserted that a blending of human intelligence, modern information technology, remote control, and intelligent autonomous systems is required, and have coined the term tele-autonomous technology, or tele-automation, for methods producing intelligent action at a distance. Tele-automation goes beyond autonomous control by blending in human intelligence. It goes beyond tele-operation by incorporating as much autonomy as possible and/or reasonable. A new approach is discussed for solving one of the fundamental problems facing tele-autonomous systems: The need to overcome time delays due to telemetry and signal propagation. New concepts are introduced called time and position clutches, that allow the time and position frames between the local user control and the remote device being controlled, to be desynchronized respectively. The design and implementation of these mechanisms are described in detail. It is demonstrated that these mechanisms lead to substantial telemanipulation performance improvements, including the result of improvements even in the absence of time delays. The new controls also yield a simple protocol for control handoffs of manipulation tasks between local operators and remote systems. Author

**N90-29795\***# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.

#### **AN ADVANCED TELEROBOTIC SYSTEM FOR SHUTTLE PAYLOAD CHANGEOUT ROOM PROCESSING APPLICATIONS**

M. SKLAR (McDonnell-Douglas Space Systems Co., Cocoa Beach, FL.) and D. WEGERIF /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 159-170 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

To potentially alleviate the inherent difficulties in the ground processing of the Space Shuttle and its associated payloads, a teleoperated, semi-autonomous robotic processing system for the Payload Changeout Room (PCR) is now in the conceptual stages. The complete PCR robotic system as currently conceived is described and critical design issues and the required technologies are discussed. E.R.

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#### **ROBOTIC TELE-EXISTENCE**

SUSUMU TACHI, HIROHIKO ARAI, and TARO MAEDA /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 171-180 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

Tele-existence is an advanced type of teleoperation system that enables a human operator at the controls to perform remote manipulation tasks dexterously with the feeling that he or she exists in the remote anthropomorphic robot in the remote environment. The concept of a tele-existence is presented, the principle of the tele-existence display method is explained, some of the prototype systems are described, and its space application is discussed. Author

**N90-29797\***# California Univ., Santa Barbara. Dept. of Mechanical and Environmental Engineering.

#### **REDUNDANCY OF SPACE MANIPULATOR ON FREE-FLYING VEHICLE AND ITS NONHOLONOMIC PATH PLANNING**

YOSHIHIKO NAKAMURA and RANJAN MUKHERJEE /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 181-190 31 Jan. 1989

Sponsored in part by NSF

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The nonholonomic mechanical structure of space robots and path planning is discussed. The angular momentum conservation works as a nonholonomic constraint while the linear momentum conservation is a holonomic one. Thus, a vehicle with a 6 d.o.f.

manipulator is described as a 9 variable system with 6 inputs. This implies the possibility of controlling the vehicle orientation and the joint variables of the manipulator by actuating the joint variables, but only if the trajectory is carefully planned; however, both of them cannot be controlled independently. It means that by assuming feasible-path planning, a system that consists of a vehicle and a 6 d.o.f. manipulator can be utilized as 9 d.o.f. system. Initially, the nonholonomic mechanical structure of space vehicle/manipulator system is shown. Then a path planning scheme for nonholonomic systems is proposed using Lyapunov functions. Author

**N90-29799\***# Florida Univ., Gainesville. Center for Intelligent Machines and Robotics.

#### **TELEPRESENCE SYSTEM DEVELOPMENT FOR APPLICATION TO THE CONTROL OF REMOTE ROBOTIC SYSTEMS**

CARL D. CRANE, III, JOSEPH DUFFY, RAJUL VORA, and SHIH-CHIEN CHIANG /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 201-210 31 Jan. 1989 Sponsored in part by DOE, Army, McDonnell Douglas Astronautics Co., and Honeywell Avail: NTIS HC A23/MF A04 CSCL 05/8

The recent developments of techniques which assist an operator in the control of remote robotic systems are described. In particular, applications are aimed at two specific scenarios: The control of remote robot manipulators; and motion planning for remote transporter vehicles. Common to both applications is the use of realistic computer graphics images which provide the operator with pertinent information. The specific system developments for several recently completed and ongoing telepresence research projects are described. Author

**N90-29800\***# California Univ., Berkeley. Telerobotics Unit.

#### **THE 3D MODEL CONTROL OF IMAGE PROCESSING**

AN H. NGUYEN and LAWRENCE STARK /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 213-222 31 Jan. 1989 Sponsored by NASA, Ames Research Center

Avail: NTIS HC A23/MF A04 CSCL 05/8

Telerobotics studies remote control of distant robots by a human operator using supervisory or direct control. Even if the robot manipulators has vision or other senses, problems arise involving control, communications, and delay. The communication delays that may be expected with telerobots working in space stations while being controlled from an Earth lab have led to a number of experiments attempting to circumvent the problem. This delay in communication is a main motivating factor in moving from well understood instantaneous hands-on manual control to less well understood supervisory control; the ultimate step would be the realization of a fully autonomous robot. The 3-D model control plays a crucial role in resolving many conflicting image processing problems that are inherent in resolving in the bottom-up approach of most current machine vision processes. The 3-D model control approach is also capable of providing the necessary visual feedback information for both the control algorithms and for the human operator. E.R.

**N90-29801\***# Purdue Univ., West Lafayette, IN. School of Electrical Engineering.

#### **WEIGHTED FEATURE SELECTION CRITERIA FOR VISUAL SERVOING OF A TELEROBOT**

JOHN T. FEDDEMA, C. S. G. LEE, and O. R. MITCHELL /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 223-233 31 Jan. 1989 Sponsored in part by IBM (Contract NSF CDR-88-03017)

Avail: NTIS HC A23/MF A04 CSCL 05/8

Because of the continually changing environment of a space station, visual feedback is a vital element of a telerobotic system. A real time visual servoing system would allow a telerobot to track and manipulate randomly moving objects. Methodologies for the automatic selection of image features to be used to visually control the relative position between an eye-in-hand telerobot and

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a known object are devised. A weighted criteria function with both image recognition and control components is used to select the combination of image features which provides the best control. Simulation and experimental results of a PUMA robot arm visually tracking a randomly moving carburetor gasket with a visual update time of 70 milliseconds are discussed.

Author

**N90-29802\***# Institut National de Recherche d'Informatique et d'Automatique, Le Chesnay (France).

### TRINOCULAR STEREOSIGHT USING FIGURAL CONTINUITY, DEALING WITH CURVED OBJECTS

R. VAILLANT and O. D. FAUGERAS /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 235-244 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

A method to build a dense and reliable 3-D description of a scene from three digital images by means of passive stereosight is presented. This method uses figural continuity to improve the results of a previously developed algorithm. In particular, it copes much better with curved objects and produces results which are organized as 3-D chains of segments.

Author

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### USE OF 3D VISION FOR FINE ROBOT MOTION

ANATOLE LOKSHIN and TODD LITWIN /n its Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 255-262 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

An integration of 3-D vision systems with robot manipulators will allow robots to operate in a poorly structured environment by visually locating targets and obstacles. However, by using computer vision for objects acquisition makes the problem of overall system calibration even more difficult. Indeed, in a CAD based manipulation a control architecture has to find an accurate mapping between the 3-D Euclidean work space and a robot configuration space (joint angles). If a stereo vision is involved, then one needs to map a pair of 2-D video images directly into the robot configuration space. Neural Network approach aside, a common solution to this problem is to calibrate vision and manipulator independently, and then tie them via common mapping into the task space. In other words, both vision and robot refer to some common Absolute Euclidean Coordinate Frame via their individual mappings. This approach has two major difficulties. First a vision system has to be calibrated over the total work space. And second, the absolute frame, which is usually quite arbitrary, has to be the same with a high degree of precision for both robot and vision subsystem calibrations. The use of computer vision to allow robust fine motion manipulation in a poorly structured world which is currently in progress is described along with the preliminary results and encountered problems.

Author

**N90-29805\***# Bolt, Beranek, and Newman, Inc., Cambridge, MA.

### TELEROBOTIC WORKSTATION DESIGN AID

K. CORKER, E. HUDLICKA, D. YOUNG, and N. CRAMER /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 265-275 31 Jan. 1989 Sponsored in part by JPL and NASA, Ames Research Center

Avail: NTIS HC A23/MF A04 CSCL 05/8

Telerobot systems are being developed to support a number of space mission applications. In low earth orbit, telerobots and teleoperated manipulators will be used in shuttle operations and space station construction/maintenance. Free flying telerobotic service vehicles will be used at low and geosynchronous orbital operations. Rovers and autonomous vehicles will be equipped with telerobotic devices in planetary exploration. In all of these systems, human operators will interact with the robot system at varied levels during the scheduled operations. The human operators may be in either orbital or ground-based control systems. To assure integrated system development and maximum utility across these systems, designers must be sensitive to the constraints and capabilities that the human brings to system operation and must be assisted

in applying these human factors to system development. The simulation and analysis system is intended to serve the needs of system analysis/designers as an integrated workstation in support of telerobotic design.

Author

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### SPACE ROBOTIC SYSTEM FOR PROXIMITY OPERATIONS

P. G. MAGNANI and M. COLOMBA /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 277-285 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

Key to an efficient accomplishment of space station servicing operations is the development of a scenario where the presence of man in space is well integrated with the capability of teleoperated and automatic robot system outside the stations. Results focusing on mission requirements, trajectory sequences, propulsion subsystem features, and manipulative kit characteristics relevant to proximity servicing during a Man Tended Free Flyers Robotic Mission (MTFF-RM) are illustrated.

E.R.

**N90-29807\***# Osaka Univ., Toyonaka (Japan). Dept. of Mechanical Engineering.

### MODELING AND SENSORY FEEDBACK CONTROL FOR SPACE MANIPULATORS

YASUHIRO MASUTANI, FUMIO MIYAZAKI, and SUGURU ARIMOTO /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 287-296 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

The positioning control problem of the endtip of space manipulators whose base are uncontrolled is examined. In such a case, the conventional control method for industrial robots based on a local feedback at each joint is not applicable, because a solution of the joint displacements that satisfies a given position and orientation of the endtip is not decided uniquely. A sensory feedback control scheme for space manipulators based on an artificial potential defined in a task-oriented coordinates is proposed. Using this scheme, the controller can easily determine the input torque of each joint from the data of an external sensor such as a visual device. Since the external sensor is mounted on the unfixed base, the manipulator must track the moving image of the target in sensor coordinates. Moreover the dynamics of the base and the manipulator are interactive. However, the endtip is proven to asymptotically approach the stationary target in an inertial coordinate frame by the Liapunov's method. Finally results of computer simulation for a 6-link space manipulator model show the effectiveness of the proposed scheme.

Author

**N90-29809\***# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

### AUTONOMOUS SENSOR-BASED DUAL-ARM SATELLITE GRAPPLING

BRIAN WILCOX, KAM TSO, TODD LITWIN, SAMAD HAYATI, and BRUCE BON /n its Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 307-316 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

Dual-arm satellite grappling involves the integration of technologies developed in the Sensing and Perception (S&P) Subsystem for object acquisition and tracking, and the Manipulator Control and Mechanization (MCM) Subsystem for dual-arm control. S&P acquires and tracks the position, orientation, velocity, and angular velocity of a slowly spinning satellite, and sends tracking data to the MCM subsystem. MCM grapples the satellite and brings it to rest, controlling the arms so that no excessive forces or torques are exerted on the satellite or arms. A 350-pound satellite mockup which can spin freely on a gimbal for several minutes, closely simulating the dynamics of a real satellite is demonstrated. The satellite mockup is fitted with a panel under which may be mounted various elements such as line replacement modules and electrical connectors that will be used to demonstrate servicing tasks once the satellite is docked. The subsystems are housed in three MicroVAX II microcomputers. The hardware of the S&P Subsystem includes CCD cameras, video digitizers, frame buffers,

IMFEX (a custom pipelined video processor), a time-code generator with millisecond precision, and a MicroVAX II computer. Its software is written in Pascal and is based on a locally written vision software library. The hardware of the MCM Subsystem includes PUMA 560 robot arms, Lord force/torque sensors, two MicroVAX II computers, and unimation pneumatic parallel grippers. Its software is written in C, and is based on a robot language called RCCL. The two subsystems are described and test results on the grappling of the satellite mockup with rotational rates of up to 2 rpm are provided.

Author

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**STABILITY ANALYSIS OF MULTIPLE-ROBOT CONTROL SYSTEMS**

JOHN T. WEN (Rensselaer Polytechnic Inst., Troy, NY.) and KENNETH KREUTZ *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 331-340 31 Jan. 1989*

Avail: NTIS HC A23/MF A04 CSCL 05/8

In a space telerobotic service scenario, cooperative motion and force control of multiple robot arms are of fundamental importance. Three paradigms to study this problem are proposed. They are distinguished by the set of variables used for control design. They are joint torques, arm tip force vectors, and an accelerated generalized coordinate set. Control issues related to each case are discussed. The latter two choices require complete model information, which presents practical modeling, computational, and robustness problems. Therefore, focus is on the joint torque control case to develop relatively model independent motion and internal force control laws. The rigid body assumption allows the motion and force control problems to be independently addressed. By using an energy motivated Lyapunov function, a simple proportional derivative plus gravity compensation type of motion control law is always shown to be stabilizing. The asymptotic convergence of the tracing error to zero requires the use of a generalized coordinate with the contact constraints taken into account. If a non-generalized coordinate is used, only convergence to a steady state manifold can be concluded. For the force control, both feedforward and feedback schemes are analyzed. The feedback control, if proper care has been taken, exhibits better robustness and transient performance.

Author

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**EXPERIMENTS IN COOPERATIVE MANIPULATION: A SYSTEM PERSPECTIVE**

STANLEY A. SCHNEIDER and ROBERT H. CANNON, JR. *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 341-350 31 Jan. 1989*

Avail: NTIS HC A23/MF A04 CSCL 05/8

In addition to cooperative dynamic control, the system incorporates real time vision feedback, a novel programming technique, and a graphical high level user interface. By focusing on the vertical integration problem, not only these subsystems are examined, but also their interfaces and interactions. The control system implements a multi-level hierarchical structure; the techniques developed for operator input, strategic command, and cooperative dynamic control are presented. At the highest level, a mouse-based graphical user interface allows an operator to direct the activities of the system. Strategic command is provided by a table-driven finite state machine; this methodology provides a powerful yet flexible technique for managing the concurrent system interactions. The dynamic controller implements object impedance control; an extension of Nevill Hogan's impedance control concept to cooperative arm manipulation of a single object. Experimental results are presented, showing the system locating and identifying a moving object catching it, and performing a simple cooperative assembly. Results from dynamic control experiments are also presented, showing the controller's excellent dynamic trajectory tracking performance, while also permitting control of environmental contact force.

Author

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**ON THE MANIPULABILITY OF DUAL COOPERATIVE ROBOTS**

P. CHIACCHIO, S. CHIAVERINI, L. SCIAVICCO, and B. SICILIANO *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 351-360 31 Jan. 1989*

Avail: NTIS HC A23/MF A04 CSCL 05/8

The definition of manipulability ellipsoids for dual robot systems is given. A suitable kineto-static formulation for dual cooperative robots is adopted which allows for a global task space description of external and internal forces, and relative velocities. The well known concepts of force and velocity manipulability ellipsoids for a single robot are formally extended and the contributions of the two single robots to the cooperative system ellipsoids are illustrated. Duality properties are discussed. A practical case study is developed.

Author

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**CONTROLLING MULTIPLE MANIPULATORS USING RIPS**

YULUN WANG, STEVE JORDAN, AMANTE MANGASER, and STEVE BUTNER *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 361-370 31 Jan. 1989 Sponsored in part by NSF and by Rockwell International*

Avail: NTIS HC A23/MF A04 CSCL 05/8

A prototype of the RIPS architecture (Robotic Instruction Processing System) was developed. A two arm robot control experiment is underway to characterize the architecture as well as research multi-arm control. This experiment uses two manipulators to cooperatively position an object. The location of the object is specified by the host computer's mouse. Consequently, real time kinematics and dynamics are necessary. The RIPS architecture is specialized so that it can satisfy these real time constraints. The two arm experimental set-up is discussed. A major part of this work is the continued development of a good programming environment for RIPS. The C++ language is employed and favorable results exist in the targeting of this language to the RIPS hardware.

Author

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**TIME OPTIMAL MOVEMENT OF COOPERATING ROBOTS**

J. M. MCCARTHY and J. E. BOBROW *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 371-379 31 Jan. 1989*

Avail: NTIS HC A23/MF A04 CSCL 05/8

The maximization of the speed of movement along a prescribed path, of the system formed by a set of robot arms and the object they hold is examined. The actuator torques that maximize the acceleration of the system are shown to be determined by the solution to a standard linear programming problem. The combination of this result with the known control strategy for time optimal movement of a single robot arm yields an algorithm for time optimal movement of multiple robot arms holding the same workpiece.

Author

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**THE FLIGHT TELEROBOTIC SERVICER PROJECT: A TECHNICAL OVERVIEW**

HARRY G. MCCAIN *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 437-445 31 Jan. 1989*

Avail: NTIS HC A23/MF A04 CSCL 05/8

The Flight Telerobotic Servicer (FTS) technical challenge is the development and integration of a spaceflight quality system with both teleoperative and autonomous capabilities. The system must be safe and reliable in the space environment. Background and rationale leading to the desired FTS telerobotic capabilities are provided. Some of the specific technical requirements to which

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the FTS must be designed in order to meet the projects goals and operate effectively in the space environment are described.

E.R.

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### **THE FLIGHT TELEROBOTIC SERVICER TINMAN CONCEPT: SYSTEM DESIGN DRIVERS AND TASK ANALYSIS**

J. F. ANDARY, D. R. HEWITT, and S. W. HINKAL /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 447-471 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

A study was conducted to develop a preliminary definition of the Flight Telerobotic Servicer (FTS) that could be used to understand the operational concepts and scenarios for the FTS. Called the Tinman, this design concept was also used to begin the process of establishing resources and interfaces for the FTS on Space Station Freedom, the National Space Transportation System shuttle orbiter, and the Orbital Maneuvering vehicle. Starting with an analysis of the requirements and task capabilities as stated in the Phase B study requirements document, the study identified eight major design drivers for the FTS. Each of these design drivers and their impacts on the Tinman design concept are described. Next, the planning that is currently underway for providing resources for the FTS on Space Station Freedom is discussed, including up to 2000 W of peak power, up to four color video channels, and command and data rates up to 500 kbps between the telerobot and the control station. Finally, an example is presented to show how the Tinman design concept was used to analyze task scenarios and explore the operational capabilities of the FTS. A structured methodology using a standard terminology consistent with the NASA/National Bureau of Standards Standard Reference Model for Telerobot Control System Architecture (NASREM) was developed for this analysis. Author

Author

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### **THE FLIGHT TELEROBOTIC SERVICER: FROM FUNCTIONAL ARCHITECTURE TO COMPUTER ARCHITECTURE**

RONALD LUMIA and JOHN FIALA /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 473-482 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

After a brief tutorial on the NASA/National Bureau of Standards Standard Reference Model for Telerobot Control System Architecture (NASREM) functional architecture, the approach to its implementation is shown. First, interfaces must be defined which are capable of supporting the known algorithms. This is illustrated by considering the interfaces required for the SERVO level of the NASREM functional architecture. After interface definition, the specific computer architecture for the implementation must be determined. This choice is obviously technology dependent. An example illustrating one possible mapping of the NASREM functional architecture to a particular set of computers which implements it is shown. The result of choosing the NASREM functional architecture is that it provides a technology independent paradigm which can be mapped into a technology dependent implementation capable of evolving with technology in the laboratory and in space. E.R.

Author

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### **RESEARCH AND DEVELOPMENT ACTIVITIES AT THE GODDARD SPACE FLIGHT CENTER FOR THE FLIGHT TELEROBOTIC SERVICER PROJECT**

STANFORD OLLENDORF /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 483-489 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

The Flight Telerobotic Servicer (FTS) is being developed by the Goddard Space Flight Center (GSFC) for performing a variety of assembly, servicing, inspection and maintenance tasks on the Space Station. The Project Office at GSFC has tasked the

Engineering Directorate to assemble a robotics research and development program which will support the FTS project. The activities center around support for the Development Test Flight (DTF) on the Space Shuttle and investigations of operational problems associated with the FTS on Space Station Freedom. For the DTF, areas such as control algorithms, safety systems, and end-effectors will be developed. For FTS operations, the emphasis will be to develop a dual-arm bi-lateral force-reflecting teleoperator and use it as an FTS Operational Simulator (FTSOS). The simulator will be used to investigate operational techniques, camera configurations, operator interfacing, orbital replacement unit (ORU) designs, end-effector designs, and training techniques. After a series of test activities, reports will be generated for input to the DTF and FTS designs.

Author

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### **THE GODDARD SPACE FLIGHT CENTER (GSFC) ROBOTICS TECHNOLOGY TESTBED**

RICK SCHNURR, MAUREEN OBRIEN, and SUE COFER (Digital Equipment Corp., Landover, MD.) /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 491-500 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

Much of the technology planned for use in NASA's Flight Telerobotic Servicer (FTS) and the Demonstration Test Flight (DTF) is relatively new and untested. To provide the answers needed to design safe, reliable, and fully functional robotics for flight, NASA/GSFC is developing a robotics technology testbed for research of issues such as zero-g robot control, dual arm teleoperation, simulations, and hierarchical control using a high-level programming language. The testbed will be used to investigate these high risk technologies required for the FTS and DTF projects. The robotics technology testbed is centered around the dual arm teleoperation of a pair of 7 degree-of-freedom (DOF) manipulators, each with their own 6-DOF mini-master hand controllers. Several levels of safety are implemented using the control processor, a separate watchdog computer, and other low level features. High speed input/output ports allow the control processor to interface to a simulation workstation: all or part of the testbed hardware can be used in real time dynamic simulation of the testbed operations, allowing a quick and safe means for testing new control strategies. The NASA/National Bureau of Standards Standard Reference Model for Telerobot Control System Architecture (NASREM) hierarchical control scheme, is being used as the reference standard for system design. All software developed for the testbed, excluding some of simulation workstation software, is being developed in Ada. The testbed is being developed in phases. The first phase, which is nearing completion, and highlights future developments is described.

Author

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### **TEST AND VALIDATION FOR ROBOT ARM CONTROL DYNAMICS SIMULATION**

K. HAROLD YAE, SUNG-SOO KIM, EDWARD J. HAUG, WARREN SEERING, KAMALA SUNDARAM, BRUCE THOMPSON, JAMES TURNER, HON CHUN (Cambridge Research Associates, MA.), HAROLD P. FRISCH, and RICHARD SCHNURR /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 501-507 31 Jan. 1989

Avail: NTIS HC A23/MF A04 CSCL 05/8

The Flight Telerobotic Servicer (FTS) program will require an ability to develop, in a cost effective manner, many simulation models for design, analysis, performance evaluation, and crew training. Computational speed and the degree of modeling fidelity associated with each simulation must be commensurate with problem objectives. To demonstrate evolving state-of-the-art general purpose multibody modeling capabilities, to validate these by laboratory testing, and to expose their modeling shortcomings, two focus problems at the opposite ends of the simulation spectrum are defined: (1) Coarse Acquisition Control Dynamics. Create a real time man-in-the-control-loop simulator. Provide animated

graphical display of robot arm dynamics and tactile feedback sufficient for cueing the operator. Interface simulator software with human operated tactile feedback controller; i.e., the Kraft mini-master. (2) Fine, Precision Mode Control Dynamics. Create a high speed, high fidelity simulation model for the design, analysis, and performance evaluation of autonomous 7 degree-of-freedom (DOF) trajectory control algorithms. This model must contain detail dynamic models for all significant dynamics elements within the robot arm, such as joint drive mechanisms.

Author

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#### HEAD-MOUNTED SPATIAL INSTRUMENTS II: SYNTHETIC REALITY OR IMPOSSIBLE DREAM

STEPHEN R. ELLIS and ARTHUR GRUNWALD (Technion - Israel Inst. of Tech., Haifa.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 521-532 31 Jan. 1989 Presented at the AGARD Meeting of the Aerospace Medicine Panel, Brussels, Belgium, 28 Sep. - 2 Oct. 1987; and at the California Mapping Conference, San Jose, CA, 1988 Previously announced as N89-12184

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A spatial instrument is defined as a spatial display which has been either geometrically or symbolically enhanced to enable a user to accomplish a particular task. Research conducted over the past several years on 3-D spatial instruments has shown that perspective displays, even when viewed from the correct viewpoint, are subject to systematic viewer biases. These biases interfere with correct spatial judgements of the presented pictorial information. The design of spatial instruments may not only require the introduction of compensatory distortions to remove the naturally occurring biases but also may significantly benefit from the introduction of artificial distortions which enhance performance. However, these image manipulations can cause a loss of visual-vestibular coordination and induce motion sickness. Consequently, the design of head-mounted spatial instruments will require an understanding of the tolerable limits of visual-vestibular discord.

Author

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#### PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 4

GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 449 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989

(Contract NAS7-918)

(NASA-CR-186859; JPL-PUBL-87-7-VOL-4; NAS 1.26:186859)

Avail: NTIS HC A19/MF A03 CSCL 05/8

Papers presented at the NASA Conference on Space Telerobotics are compiled. The theme of the conference was man-machine collaboration in space. The conference provided a forum for researchers and engineers to exchange ideas on the research and development required for the application of telerobotic technology to the space systems planned for the 1990's and beyond. Volume 4 contains papers related to the following subject areas: manipulator control; telemanipulation; flight experiments (systems and simulators); sensor-based planning; robot kinematics, dynamics, and control; robot task planning and assembly; and research activities at the NASA Langley Research Center.

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#### AN IMPROVED ADAPTIVE CONTROL FOR REPETITIVE MOTION OF ROBOTS

F. POURBOGHRAT *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 3-10 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

An adaptive control algorithm is proposed for a class of nonlinear systems, such as robotic manipulators, which is capable of improving its performance in repetitive motions. When the task is repeated, the error between the desired trajectory and that of

the system is guaranteed to decrease. The design is based on the combination of a direct adaptive control and a learning process. This method does not require any knowledge of the dynamic parameters of the system.

Author

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#### MODEL BASED MANIPULATOR CONTROL

LYMAN J. PETROSKY and IRVING J. OPPENHEIM (Carnegie-Mellon Univ., Pittsburgh, PA.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 23-32 31 Jan. 1989 (Contract DE-AC02-85NE-37947)

Avail: NTIS HC A19/MF A03 CSCL 05/8

The feasibility of using model based control (MBC) for robotic manipulators was investigated. A double inverted pendulum system was constructed as the experimental system for a general study of dynamically stable manipulation. The original interest in dynamically stable systems was driven by the objective of high vertical reach (balancing), and the planning of inertially favorable trajectories for force and payload demands. The model-based control approach is described and the results of experimental tests are summarized. Results directly demonstrate that MBC can provide stable control at all speeds of operation and support operations requiring dynamic stability such as balancing. The application of MBC to systems with flexible links is also discussed.

M.G.

**N90-29834\***# California Univ., San Diego, La Jolla. Space Inst. DISCRETE-TIME ADAPTIVE CONTROL OF ROBOT MANIPULATORS

M. TAROKH *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 33-42 31 Jan. 1989 Previously announced in IAA as A90-29974

Avail: NTIS HC A19/MF A03 CSCL 05/8

A discrete-time model reference adaptive control scheme is developed for trajectory tracking of robot manipulators. Hyperstability theory is utilized to derive the adaptation laws for the controller gain matrices. It is shown that asymptotic trajectory tracking is achieved despite gross robot parameter variation and uncertainties. The method offers considerable design flexibility and enables the designer to improve the performance of the control system by adjusting free design parameters. The discrete-time adaptation algorithm is extremely simple and is therefore suitable for real-time implementation.

Author

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#### A DISCRETE DECENTRALIZED VARIABLE STRUCTURE ROBOTIC CONTROLLER

ZUHEIR S. TUMEH *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 43-52 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

A decentralized trajectory controller for robotic manipulators is designed and tested using a multiprocessor architecture and a PUMA 560 robot arm. The controller is made up of a nominal model-based component and a correction component based on a variable structure suction control approach. The second control component is designed using bounds on the difference between the used and actual values of the model parameters. Since the continuous manipulator system is digitally controlled along a trajectory, a discretized equivalent model of the manipulator is used to derive the controller. The motivation for decentralized control is that the derived algorithms can be executed in parallel using a distributed, relatively inexpensive, architecture where each joint is assigned a microprocessor. Nonlinear interaction and coupling between joints is treated as a disturbance torque that is estimated and compensated for.

Author

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#### CONSTRUCTION AND DEMONSTRATION OF A 9-STRING 6 DOF FORCE REFLECTING JOYSTICK FOR TELEROBOTICS

## 54 MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

RANDEL LINDEMANN and DELBERT TESAR (Texas Univ., Austin.) *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 55-63 31 Jan. 1989*  
Avail: NTIS HC A19/MF A03 CSCL 05/8

Confrontation with difficult manipulation tasks in hostile environments such as space, has led to the development of means to transport the human's senses, skills and cognition to the remote site. The use of advanced Telerobotics to achieve this goal is examined. A novel and universal hand controller based on a fully parallel mechanical architecture is discussed. The design and implementation of this 6 DOF force reflecting joystick is shown in relationship to the general philosophy of achieving telepresence in a man-machine system.

Author

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**RESPONSE TO REFLECTED-FORCE FEEDBACK TO FINGERS IN TELEOPERATIONS**

P. H. SUTTER, J. C. IATRIDIS, and N. V. THAKOR (Johns Hopkins Univ., Baltimore, MD.) *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 65-74 31 Jan. 1989 Sponsored in part by Johns Hopkins Univ., Baltimore, MD*

Avail: NTIS HC A19/MF A03 CSCL 05/8

Reflected-force feedback is an important aspect of teleoperations. The objective is to determine the ability of the human operator to respond to that force. Telerobotics operation is simulated by computer control of a motor-driven device with capabilities for programmable force feedback and force measurement. A computer-controlled motor drive is developed that provides forces against the fingers as well as (angular) position control. A load cell moves in a circular arc as it is pushed by a finger and measures reaction forces on the finger. The force exerted by the finger on the load cell and the angular position are digitized and recorded as a function of time by the computer. Flexure forces of the index, long and ring fingers of the human hand in opposition to the motor driven load cell are investigated. Results of the following experiments are presented: (1) Exertion of maximum finger force as a function of angle; (2) Exertion of target finger force against a computer controlled force; and (3) Test of the ability to move to a target force against a force that is a function of position. Averaged over ten individuals, the maximum force that could be exerted by the index or long finger is about 50 Newtons, while that of the ring finger is about 40 Newtons. From the tests of the ability of a subject to exert a target force, it was concluded that reflected-force feedback can be achieved with the direct kinesthetic perception of force without the use of tactile or visual clues.

Author

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**THE JAU-JPL ANTHROPOMORPHIC TELEROBOT**

BRUNO M. JAU *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 75-80 31 Jan. 1989*  
Avail: NTIS HC A19/MF A03 CSCL 05/8

Work in progress on the new anthropomorphic telerobot is described. The initial robot configuration consists of a seven DOF arm and a sixteen DOF hand, having three fingers and a thumb. The robot has active compliance, enabling subsequent dual arm manipulations. To control the rather complex configuration of this robot, an exoskeleton master arm harness and a glove controller were built. The controller will be used for teleoperational tasks and as a research tool to efficiently teach the computer controller advanced manipulation techniques.

Author

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**A PROCEDURE CONCEPT FOR LOCAL REFLEX CONTROL OF GRASPING**

PAOLO FIORINI and JEFFREY CHANG *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 81-90 31 Jan. 1989*  
Avail: NTIS HC A19/MF A03 CSCL 05/8

An architecture is proposed for the control of robotic devices,

and in particular of anthropomorphic hands, characterized by a hierarchical structure in which every level of the architecture contains data and control function with varying degree of abstraction. Bottom levels of the hierarchy interface directly with sensors and actuators, and process raw data and motor commands. Higher levels perform more symbolic types of tasks, such as application of boolean rules and general planning operations. Layers implementation has to be consistent with the type of operation and its requirements for real time control. It is proposed to implement the rule level with a Boolean Artificial Neural Network characterized by a response time sufficient for producing reflex corrective action at the actuator level.

Author

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**PERFORMANCE LIMITATIONS OF BILATERAL FORCE REFLECTION IMPOSED BY OPERATOR DYNAMIC CHARACTERISTICS**

JIM D. CHAPEL *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 91-100 31 Jan. 1989*

Avail: NTIS HC A19/MF A03 CSCL 05/8

A linearized, single-axis model is presented for bilateral force reflection which facilitates investigation into the effects of manipulator, operator, and task dynamics, as well as time delay and gain scaling. Structural similarities are noted between this model and impedance control. Stability results based upon this model impose requirements upon operator dynamic characteristics as functions of system time delay and environmental stiffness. An experimental characterization reveals the limited capabilities of the human operator to meet these requirements. A procedure is presented for determining the force reflection gain scaling required to provide stability and acceptable operator workload. This procedure is applied to a system with dynamics typical of a space manipulator, and the required gain scaling is presented as a function of environmental stiffness.

Author

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**SENSOR-BASED FINE TELEMANIPULATION FOR SPACE ROBOTICS**

M. ANDRENUCCI, M. BERGAMASCO (Scuola Normale Superiore, Pisa, Italy), and P. DARIO *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 101-107 31 Jan. 1989*

Avail: NTIS HC A19/MF A03 CSCL 05/8

The control of a multifingered hand slave in order to accurately exert arbitrary forces and impart small movements to a grasped object is, at present, a knotty problem in teleoperation. Although a number of articulated robotic hands have been proposed in the recent past for dexterous manipulation in autonomous robots, the possible use of such hands as slaves in teleoperated manipulation is hindered by the present lack of sensors in those hands, and (even if those sensors were available) by the inherent difficulty of transmitting to the master operator the complex sensations elicited by such sensors at the slave level. An analysis of different problems related to sensor-based telemannipulation is presented. The general sensory systems requirements for dexterous slave manipulators are pointed out and the description of a practical sensory system set-up for the developed robotic system is presented. The problem of feeding back to the human master operator stimuli that can be interpreted by his central nervous system as originated during real dexterous manipulation is then considered. Finally, some preliminary work aimed at developing an instrumented glove designed purposely for commanding the master operation and incorporating Kevlar tendons and tension sensors, is discussed.

Author

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**ROTEX-TRIIFEX: PROPOSAL FOR A JOINT FRG-USA TELEROBOTIC FLIGHT EXPERIMENT**

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Raumfahrt, Oberpfaffenhofen, Germany, F.R.) and A. K. BEJCZY  
*In its Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 111-123 31 Jan. 1989*  
 Avail: NTIS HC A19/MF A03 CSCL 05/8

The concepts and main elements of a RObot Technology EXperiment (ROTEX) proposed to fly with the next German spacelab mission, D2, are presented. It provides a 1 meter size, six axis robot inside a spacelab rack, equipped with a multisensor gripper (force-torque sensors, an array of range finders, and mini stereo cameras). The robot will perform assembly and servicing tasks in a generic way, and will grasp a floating object. The man machine and supervisory control concepts for teleoperation from the spacelab and from ground are discussed. The predictive estimation schemes for an extensive use of time-delay compensating 3D computer graphics are explained. Author

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**TEST AND TRAINING SIMULATOR FOR GROUND-BASED TELEOPERATED IN-ORBIT SERVICING**

BERND E. SCHAEFER *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 125-134 31 Jan. 1989*  
 (Contract DFVLR-5-575-4359)

Avail: NTIS HC A19/MF A03 CSCL 05/8

For the Post-IOC(In-Orbit Construction)-Phase of COLUMBUS it is intended to use robotic devices for the routine operations of ground-based teleoperated In-Orbit Servicing. A hardware simulator for verification of the relevant in-orbit operations technologies, the Servicing Test Facility, is necessary which mainly will support the Flight Control Center for the Manned Space-Laboratories for operational specific tasks like system simulation, training of teleoperators, parallel operation simultaneously to actual in-orbit activities and for the verification of the ground operations segment for telerobotics. The present status of definition for the facility functional and operational concept is described. Author

**N90-29844\***# European Space Agency, European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).

**CONCEPT SYNTHESIS OF AN EQUIPMENT MANIPULATION AND TRANSPORTATION SYSTEM EMATS**

W. DEPEUTER and E. WAFFENSCHMIDT (Dornier-Werke G.m.b.H., Friedrichshafen, Germany, F.R.) *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 135-143 31 Jan. 1989*

Avail: NTIS HC A19/MF A03 CSCL 05/8

The European Columbus Scenario is established. One of the Columbus Elements, the Man Tended Free Flyer will be designed for fully autonomous operation in order to provide the environment for micro gravity facilities. The Concept of an autonomous automation system which perform servicing of facilities and deals with related logistic tasks is discussed. Author

**N90-29845\***# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**FORCE-REFLECTIVE TELEOPERATED SYSTEM WITH SHARED AND COMPLIANT CONTROL CAPABILITIES**

Z. SZAKALY, W. S. KIM, and A. K. BEJCZY *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 145-155 31 Jan. 1989*

Avail: NTIS HC A19/MF A03 CSCL 05/8

The force-reflecting teleoperator breadboard is described. It is the first system among available Research and Development systems with the following combined capabilities: (1) The master input device is not a replica of the slave arm. It is a general purpose device which can be applied to the control of different robot arms through proper mathematical transformations. (2) Force reflection generated in the master hand controller is referenced to forces and moments measured by a six DOF force-moment sensor at the base of the robot hand. (3) The system permits a smooth spectrum of operations between full manual, shared manual and automatic, and full automatic (called traded) control. (4) The

system can be operated with variable compliance or stiffness in force-reflecting control. Some of the key points of the system are the data handling and computing architecture, the communication method, and the handling of mathematical transformations. The architecture is a fully synchronized pipeline. The communication method achieves optimal use of a parallel communication channel between the local and remote computing nodes. A time delay box is also implemented in this communication channel permitting experiments with up to 8 sec time delay. The mathematical transformations are computed faster than 1 msec so that control at each node can be operated at 1 kHz servo rate without interpolation. This results in an overall force-reflecting loop rate of 200 Hz. Author

**N90-29847\***# Politecnico di Milano (Italy). Dept. of Mechanics.  
**REDUNDANCY IN SENSORS, CONTROL AND PLANNING OF A ROBOTIC SYSTEM FOR SPACE TELEROBOTICS**

A. ROVETTA, S. VODRET, and M. BIANCHINI *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 167-170 31 Jan. 1989*

Avail: NTIS HC A19/MF A03 CSCL 05/8

The analysis and development of a manipulator redundant in structure and sensor devices controlled by a distributed multiprocessor architecture are discussed. The goal has been the realization of a modular structure of the manipulator with evident aspects of flexibility and transportability. The distributed control structure, thanks to his modularity and flexibility could be integrated in the future into an operative structure aimed to space telerobotics. The architecture is applied to the 6 DOF manipulator Gilberto. Author

**N90-29848\***# Carnegie-Mellon Univ., Pittsburgh, PA. Dept. of Computer Science.

**HOW TO PUSH A BLOCK ALONG A WALL**

MATTHEW T. MASON *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 173-182 31 Jan. 1989*

Avail: NTIS HC A19/MF A03 CSCL 05/8

Some robot tasks require manipulation of objects that may be touching other fixed objects. The effects of friction and kinematic constraint must be anticipated, and may even be exploited to accomplish the task. An example task, a dynamic analysis, and appropriate effector motions are presented. The goal is to move a rectangular block along a wall, so that one side of the block maintains contact with the wall. Two solutions that push the block along the wall are discussed. Author

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**GLOBAL MODELS: ROBOT SENSING, CONTROL, AND SENSORY-MOTOR SKILLS**

PAUL S. SCHENKER *In its Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 183-186 31 Jan. 1989*  
 Avail: NTIS HC A19/MF A03 CSCL 05/8

Robotics research has begun to address the modeling and implementation of a wide variety of unstructured tasks. Examples include automated navigation, platform servicing, custom fabrication and repair, deployment and recovery, and science exploration. Such tasks are poorly described at onset; the workspace layout is partially unfamiliar, and the task control sequence is only qualitatively characterized. The robot must model the workspace, plan detailed physical actions from qualitative goals, and adapt its instantaneous control regimes to unpredicted events. Developing robust representations and computational approaches for these sensing, planning, and control functions is a major challenge. The underlying domain constraints are very general, and seem to offer little guidance for well-bounded approximation of object shape and motion, manipulation postures and trajectories, and the like. This generalized modeling problem is discussed, with an emphasis on the role of sensing. It is also discussed that unstructured tasks often have, in fact, a high degree of underlying physical symmetry, and such implicit knowledge should be drawn on to model task performance strategies in a methodological fashion. A

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group-theoretic decomposition of the workspace organization, task goals, and their admissible interactions are proposed. This group-mechanical approach to task representation helps to clarify the functional interplay of perception and control, in essence, describing what perception is specifically for, versus how it is generically modeled. One also gains insight how perception might logically evolve in response to needs of more complex motor skills. It is discussed why, of the many solutions that are often mathematically admissible to a given sensory motor-coordination problem, one may be preferred over others.

Author

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### THE 3-D VISION SYSTEM INTEGRATED DEXTEROUS HAND

REN C. LUO and YOUN-SIK HAN /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 187-195 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

Most multifingered hands use a tendon mechanism to minimize the size and weight of the hand. Such tendon mechanisms suffer from the problems of striction and friction of the tendons resulting in a reduction of control accuracy. A design for a 3-D vision system integrated dexterous hand with motor control is described which overcomes these problems. The proposed hand is composed of three three-jointed grasping fingers with tactile sensors on their tips, a two-jointed eye finger with a cross-shaped laser beam emitting diode in its distal part. The two non-grasping fingers allow 3-D vision capability and can rotate around the hand to see and measure the sides of grasped objects and the task environment. An algorithm that determines the range and local orientation of the contact surface using a cross-shaped laser beam is introduced along with some potential applications. An efficient method for finger force calculation is presented which uses the measured contact surface normals of an object.

M.G.

**N90-29851\***# Ohio State Univ., Columbus. Lab. for Artificial Intelligence Research.

### A LAYERED ABDUCTION MODEL OF PERCEPTION: INTEGRATING BOTTOM-UP AND TOP-DOWN PROCESSING IN A MULTI-SENSE AGENT

JOHN R. JOSEPHSON /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 197-206 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

A layered-abduction model of perception is presented which unifies bottom-up and top-down processing in a single logical and information-processing framework. The process of interpreting the input from each sense is broken down into discrete layers of interpretation, where at each layer a best explanation hypothesis is formed of the data presented by the layer or layers below, with the help of information available laterally and from above. The formation of this hypothesis is treated as a problem of abductive inference, similar to diagnosis and theory formation. Thus this model brings a knowledge-based problem-solving approach to the analysis of perception, treating perception as a kind of compiled cognition. The bottom-up passing of information from layer to layer defines channels of information flow, which separate and converge in a specific way for any specific sense modality. Multi-modal perception occurs where channels converge from more than one sense. This model has not yet been implemented, though it is based on systems which have been successful in medical and mechanical diagnosis and medical test interpretation.

Author

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### RCTS: A FLEXIBLE ENVIRONMENT FOR SENSOR INTEGRATION AND CONTROL OF ROBOT SYSTEMS; THE DISTRIBUTED PROCESSING APPROACH

R. ALLARD, B. MACK, and M. M. BAYOUMI /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 207-216 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

Most robot systems lack a suitable hardware and software

environment for the efficient research of new control and sensing schemes. Typically, engineers and researchers need to be experts in control, sensing, programming, communication and robotics in order to implement, integrate and test new ideas in a robot system. In order to reduce this time, the Robot Controller Test Station (RCTS) has been developed. It uses a modular hardware and software architecture allowing easy physical and functional reconfiguration of a robot. This is accomplished by emphasizing four major design goals: flexibility, portability, ease of use, and ease of modification. An enhanced distributed processing version of RCTS is described. It features an expanded and more flexible communication system design. Distributed processing results in the availability of more local computing power and retains the low cost of microprocessors. A large number of possible communication, control and sensing schemes can therefore be easily introduced and tested, using the same basic software structure.

Author

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### VEHICLE PATH-PLANNING IN THREE DIMENSIONS USING OPTICS ANALOGS FOR OPTIMIZING VISIBILITY AND ENERGY COST

NEIL C. ROWE and DAVID H. LEWIS /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 217-226 31 Jan. 1989

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Path planning is an important issue for space robotics. Finding safe and energy-efficient paths in the presence of obstacles and other constraints can be complex although important. High-level (large-scale) path planning for robotic vehicles was investigated in three-dimensional space with obstacles, accounting for: (1) energy costs proportional to path length; (2) turn costs where paths change trajectory abruptly; and (3) safety costs for the danger associated with traversing a particular path due to visibility or invisibility from a fixed set of observers. Paths optimal with respect to these cost factors are found. Autonomous or semi-autonomous vehicles were considered operating either in a space environment around satellites and space platforms, or aircraft, spacecraft, or smart missiles operating just above lunar and planetary surfaces. One class of applications concerns minimizing detection, as for example determining the best way to make complex modifications to a satellite without being observed by hostile sensors; another example is verifying there are no paths (holes) through a space defense system. Another class of applications concerns maximizing detection, as finding a good trajectory between mountain ranges of a planet while staying reasonably close to the surface, or finding paths for a flight between two locations that maximize the average number of triangulation points available at any time along the path.

Author

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### VACUUM MECHATRONICS

SUSAN HACKWOOD, STEVEN E. BELINSKI, and GERARDO BENI /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 229-240 31 Jan. 1989

(Contract NSF CDR-84-21415; SRC88-MP-121)

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The discipline of vacuum mechatronics is defined as the design and development of vacuum-compatible computer-controlled mechanisms for manipulating, sensing and testing in a vacuum environment. The importance of vacuum mechatronics is growing with an increased application of vacuum in space studies and in manufacturing for material processing, medicine, microelectronics, emission studies, lyophilisation, freeze drying and packaging. The quickly developing field of vacuum mechatronics will also be the driving force for the realization of an advanced era of totally enclosed clean manufacturing cells. High technology manufacturing has increasingly demanding requirements for precision manipulation, in situ process monitoring and contamination-free environments. To remove the contamination problems associated

with human workers, the tendency in many manufacturing processes is to move towards total automation. This will become a requirement in the near future for e.g., microelectronics manufacturing. Automation in ultra-clean manufacturing environments is evolving into the concept of self-contained and fully enclosed manufacturing. A Self Contained Automated Robotic Factory (SCARF) is being developed as a flexible research facility for totally enclosed manufacturing. The construction and successful operation of a SCARF will provide a novel, flexible, self-contained, clean, vacuum manufacturing environment. SCARF also requires very high reliability and intelligent control. The trends in vacuum mechatronics and some of the key research issues are reviewed.

Author

**N90-29855\*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**UNIFORM TASK LEVEL DEFINITIONS FOR ROBOTIC SYSTEM PERFORMANCE COMPARISONS**

CHARLES PRICE and DELBERT TESAR (Texas Univ., Austin.) *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 241-244* 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

A series of ten task levels of increasing difficulty was compiled for use in comparative performance evaluations of available and future robotics technology. Each level has a breakdown of ten additional levels of difficulty to provide a layering of 100 levels. It is assumed that each level of task performance must be achieved by the system before it can be appropriately considered for the next level.

Author

**N90-29856\*#** Utah Univ., Salt Lake City. Center for Engineering Design.

**LINEAR ANALYSIS OF A FORCE REFLECTIVE TELEOPERATOR**

KLAUS B. BIGGERS, STEPHEN C. JACOBSEN, and CLARK C. DAVIS *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 245-254* 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

Complex force reflective teleoperation systems are often very difficult to analyze due to the large number of components and control loops involved. One mode of a force reflective teleoperator is described. An analysis of the performance of the system based on a linear analysis of the general full order model is presented. Reduced order models are derived and correlated with the full order models. Basic effects of force feedback and position feedback are examined and the effects of time delays between the master and slave are studied. The results show that with symmetrical position-position control of teleoperators, a basic trade off must be made between the intersystem stiffness of the teleoperator, and the impedance felt by the operator in free space.

Author

**N90-29857\*#** Lockheed Engineering and Sciences Co., Houston, TX.

**REAL-TIME CARTESIAN FORCE FEEDBACK CONTROL OF A TELEOPERATED ROBOT**

PERRY CAMPBELL *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 255-262* 31 Jan. 1989

(Contract NAS9-17900)

Avail: NTIS HC A19/MF A03 CSCL 05/8

Active cartesian force control of a teleoperated robot is investigated. An economical microcomputer based control method was tested. Limitations are discussed and methods of performance improvement suggested. To demonstrate the performance of this technique, a preliminary test was performed with success. A general purpose bilateral force reflecting hand controller is currently being constructed based on this control method.

Author

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**OPTIMAL PAYLOAD RATE LIMIT ALGORITHM FOR ZERO-G MANIPULATORS**

M. L. ROSS and D. A. MCDERMOTT *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 263-272* 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

An algorithm for continuously computing safe maximum relative velocities for two bodies joined by a manipulator is discussed. The maximum velocities are such that if the brakes are applied at that instant, the ensuing travel between the bodies will be less than or equal to a predetermined amount. An improvement in the way this limit is computed for space manipulators is shown. The new method is explained, test cases are posed, and the results of these tests are displayed and discussed.

Author

**N90-29859\*#** IBM Italia, Rome. Scientific Center.

**ASSEMBLY OF OBJECTS WITH NOT FULLY PREDEFINED SHAPES**

M. A. ARLOTTI and V. DIMARTINO *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 273-282* 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

An assembly problem in a non-deterministic environment, i.e., where parts to be assembled have unknown shape, size and location, is described. The only knowledge used by the robot to perform the assembly operation is given by a connectivity rule and geometrical constraints concerning parts. Once a set of geometrical features of parts has been extracted by a vision system, applying such a rule allows the determination of the composition sequence. A suitable sensory apparatus allows the control the whole operation.

Author

**N90-29865\*#** Pennsylvania Univ., Philadelphia. Dept. of Computer and Information Science.

**ON THE STABILITY OF ROBOTIC SYSTEMS WITH RANDOM COMMUNICATION RATES**

H. KOBAYASHI (Meiji Univ., Kawasaki, Japan), X. YUN, and R. P. PAUL *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 341-350* 31 Jan. 1989 Sponsored in part by NSF

Avail: NTIS HC A19/MF A03 CSCL 05/8

Control problems of sampled data systems which are subject to random sample rate variations and delays are studied. Due to the rapid growth of the use of computers more and more systems are controlled digitally. Complex systems such as space telerobotic systems require the integration of a number of subsystems at different hierarchical levels. While many subsystems may run on a single processor, some subsystems require their own processor or processors. The subsystems are integrated into functioning systems through communications. Communications between processes sharing a single processor are also subject to random delays due to memory management and interrupt latency. Communications between processors involve random delays due to network access and to data collisions. Furthermore, all control processes involve delays due to causal factors in measuring devices and to signal processing. Traditionally, sampling rates are chosen to meet the worst case communication delay. Such a strategy is wasteful as the processors are then idle a great proportion of the time; sample rates are not as high as possible resulting in poor performance or in the over specification of control processors; there is the possibility of missing data no matter how low the sample rate is picked. Asymptotical stability with probability one for randomly sampled multi-dimensional linear systems is studied. A sufficient condition for the stability is obtained. This condition is so simple that it can be applied to practical systems. A design procedure is also shown.

Author

**N90-29866\*#** Carnegie-Mellon Univ., Pittsburgh, PA. The Robotics Inst.

**PRECEDENCE RELATIONSHIP REPRESENTATIONS OF MECHANICAL ASSEMBLY SEQUENCES**

L. S. HOMENDEMELLO and A. C. SANDERSON (Rensselaer Polytechnic Inst., Troy, NY.) *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 353-362 31 Jan. 1989 Sponsored in part by the Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil; JPL; and Carnegie Mellon Univ.*

Avail: NTIS HC A19/MF A03 CSCL 05/8

Two types of precedence relationship representations for mechanical assembly sequences are presented: precedence relationships between the establishment of one connection between two parts and the establishment of another connection, and precedence relationships between the establishment of one connection and states of the assembly process. Precedence relationship representations have the advantage of being very compact. The problem with these representations was how to guarantee their correctness and completeness. Two theorems are presented each of which leads to the generation of one type of precedence relationship representation guaranteeing its correctness and completeness for a class of assemblies. Author

**N90-29868\*# Honeywell, Inc., Minneapolis, MN.  
DETERMINING ROBOT ACTIONS FOR TASKS REQUIRING  
SENSOR INTERACTION**

JOHN BUDENSKE and MARIA GINI (Minnesota Univ., Minneapolis.) *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 373-382 31 Jan. 1989*

(Contract NSF DMC-85-18735)

Avail: NTIS HC A19/MF A03 CSCL 05/8

The performance of non-trivial tasks by a mobile robot has been a long term objective of robotic research. One of the major stumbling blocks to this goal is the conversion of the high-level planning goals and commands into the actuator and sensor processing controls. In order for a mobile robot to accomplish a non-trivial task, the task must be described in terms of primitive actions of the robot's actuators. Most non-trivial tasks require the robot to interact with its environment; thus necessitating coordination of sensor processing and actuator control to accomplish the task. The main contention is that the transformation from the high level description of the task to the primitive actions should be performed primarily at execution time, when knowledge about the environment can be obtained through sensors. It is proposed to produce the detailed plan of primitive actions by using a collection of low-level planning components that contain domain specific knowledge and knowledge about the available sensors, actuators, and sensor/actuator processing. This collection will perform signal and control processing as well as serve as a control interface between an actual mobile robot and a high-level planning system. Previous research has shown the usefulness of high-level planning systems to plan the coordination of activities such to achieve a goal, but none have been fully applied to actual mobile robots due to the complexity of interacting with sensors and actuators. This control interface is currently being implemented on a LABMATE mobile robot connected to a SUN workstation and will be developed such to enable the LABMATE to perform non-trivial, sensor-intensive tasks as specified by a planning system. Author

**N90-29869\*# Oak Ridge National Lab., TN.  
THE LABORATORY TELEROBOTIC MANIPULATOR  
PROGRAM**

J. N. HERNDON, S. M. BABCOCK, P. L. BUTLER, H. M. COSTELLO, R. L. GLASSELL, R. L. KRESS, D. P. KUBAN, J. C. ROWE, and D. M. WILLIAMS *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 385-393 31 Jan. 1989 Sponsored in part by NASA, Langley Research Center*

(Contract DE-AC05-84OR-21400)

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New opportunities for the application of telerobotic systems to enhance human intelligence and dexterity in the hazardous environment of space are presented by the NASA Space Station Program. Because of the need for significant increases in

extravehicular activity and the potential increase in hazards associated with space programs, emphasis is being heightened on telerobotic systems research and development. The Laboratory Telerobotic Manipulator (LTM) program is performed to develop and demonstrate ground-based telerobotic manipulator system hardware for research and demonstrations aimed at future NASA applications. The LTM incorporates traction drives, modularity, redundant kinematics, and state-of-the-art hierarchical control techniques to form a basis for merging the diverse technological domains of robust, high-dexterity teleoperations and autonomous robotic operation into common hardware to further NASA's research. Author

**N90-29870\*# Tennessee Univ., Knoxville. Dept. of Mechanical and Aerospace Engineering.**

**ROBOTIC CONTROL OF THE SEVEN-DEGREE-OF-FREEDOM  
NASA LABORATORY TELEROBOTIC MANIPULATOR**

R. V. DUBEY, J. A. EULER, R. B. MAGNESS, S. M. BABCOCK, and J. N. HERNDON (Oak Ridge National Lab., TN.) *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 395-407 31 Jan. 1989 Sponsored in part by NASA, Langley Research Center*

(Contract DE-AC05-84OR-21400)

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A computationally efficient robotic control scheme for the NASA Laboratory Telerobotic Manipulator (LTM) is presented. This scheme utilizes the redundancy of the seven-degree-of-freedom LTM to avoid joint limits and singularities. An analysis to determine singular configurations is presented. Performance criteria are determined based on the joint limits and singularity analysis. The control scheme is developed in the framework of resolved rate control using the gradient projection method, and it does not require the generalized inverse of the Jacobian. An efficient formulation for determining the joint velocities of the LTM is obtained. This control scheme is well suited for real-time implementation, which is essential if the end-effector trajectory is continuously modified based on sensory feedback. Implementation of this scheme on a Motorola 68020 VME bus-based controller of the LTM is in progress. Simulation results demonstrating the redundancy utilization in the robotic mode are presented. Author

**N90-29871\*# Massachusetts Inst. of Tech., Cambridge. Dept. of Mechanical Engineering.**

**THE CONTROL OF SPACE MANIPULATORS SUBJECT TO  
SPACECRAFT ATTITUDE CONTROL SATURATION LIMITS**

S. DUBOWSKY, E. E. VANCE, and M. A. TORRES *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 409-418 31 Jan. 1989 Sponsored in part by NASA, Langley Research Center*

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The motions of robotic manipulators mounted on spacecraft can disturb the spacecraft's positions and attitude. These disturbances can surpass the ability of the system's attitude control reaction jets to control them, for the disturbances increase as manipulator speeds increase. If the manipulator moves too quickly the resulting disturbances can exceed the saturation levels of the reaction jets, causing excessive spacecraft motions. A method for planning space manipulator's motions is presented, so that tasks can be performed as quickly as possible without saturating the system's attitude control jets. Author

**N90-29872\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.**

**SYSTEM ARCHITECTURES FOR TELEROBOTIC RESEARCH**

F. WALLACE HARRISON *In JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 419-429 31 Jan. 1989 Sponsored in part by NASA, Langley Research Center*

Avail: NTIS HC A19/MF A03 CSCL 05/8

Several activities are performed related to the definition and creation of telerobotic systems. The effort and investment required to create architectures for these complex systems can be enormous; however, the magnitude of process can be reduced if structured design techniques are applied. A number of informal

methodologies supporting certain aspects of the design process are available. More recently, prototypes of integrated tools supporting all phases of system design from requirements analysis to code generation and hardware layout have begun to appear. Activities related to system architecture of telerobots are described, including current activities which are designed to provide a methodology for the comparison and quantitative analysis of alternative system architectures.

Author

**N90-29873\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**COMPARISON OF JOINT SPACE VERSUS TASK FORCE LOAD DISTRIBUTION OPTIMIZATION FOR A MULTIRARM MANIPULATOR SYSTEM**

DONALD I. SOLOWAY and THOMAS E. ALBERTS (Old Dominion Univ., Norfolk, VA.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 431-443 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

It is often proposed that the redundancy in choosing a force distribution for multiple arms grasping a single object should be handled by minimizing a quadratic performance index. The performance index may be formulated in terms of joint torques or in terms of the Cartesian space force/torque applied to the body by the grippers. The former seeks to minimize power consumption while the latter minimizes body stresses. Because the cost functions are related to each other by a joint angle dependent transformation on the weight matrix, it might be argued that either method tends to reduce power consumption, but clearly the joint space minimization is optimal. A comparison of these two options is presented with consideration given to computational cost and power consumption. Simulation results using a two arm robot system are presented to show the savings realized by employing the joint space optimization. These savings are offset by additional complexity, computation time and in some cases processor power consumption.

Author

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**PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 5**

GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 428 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989

(Contract NAS7-918)

(NASA-CR-186860; JPL-PUBL-89-7-VOL-5; NAS 1.26:186860)

Avail: NTIS HC A19/MF A03 CSCL 05/8

Papers presented at the NASA Conference on Space Telerobotics are compiled. The theme of the conference was man-machine collaboration in space. The conference provided a forum for researchers and engineers to exchange ideas on the research and development required for the application of telerobotics technology to the space systems planned for the 1990's and beyond. Volume 5 contains papers related to the following subject areas: robot arm modeling and control, special topics in telerobotics, telerobotic space operations, manipulator control, flight experiment concepts, manipulator coordination, issues in artificial intelligence systems, and research activities at the Johnson Space Center.

**N90-29875\*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**TELEROBOTIC ACTIVITIES AT JOHNSON SPACE CENTER**

CHARLES R. PRICE *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 3-7 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

The Johnson Space Center telerobotic efforts span three major thrusts: (1) sustaining and expanding the capability of the Shuttle manipulator; (2) developing and integrating the multiple telerobotic system of the Space Station; and (3) fostering and applying research in all areas of telerobotics technology within the government, private, and academic sectors.

Author

**N90-29876\*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**APPLICATION OF RECURSIVE MANIPULATOR DYNAMICS TO HYBRID SOFTWARE/HARDWARE SIMULATION**

CHRISTOPHER J. HILL, KENNETH A. HOPPING (Boeing Electronics Co., Bellevue, WA.), and CHARLES R. PRICE *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 11-20 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

Computer simulations of robotic mechanisms have traditionally solved the dynamic equations of motion for an N degree of freedom manipulator by formulating an N dimensional matrix equation combining the accelerations and torques (forces) for all joints. The use of an alternative formulation that is strictly recursive is described. The dynamic solution proceeds on a joint by joint basis, so it is possible to perform inverse dynamics at arbitrary joints. The dynamic formulation is generalized with respect to both rotational and translational joints, and it is also directly extendable to branched manipulator chains. A hardware substitution test is described in which a servo drive motor was integrated with a simulated manipulator arm. The form of the dynamic equation permits calculation of acceleration given torque or vice versa. Computing torque as a function of acceleration is required for the hybrid software/hardware simulation test described. For this test, a joint servo motor is controlled in conjunction with the simulation, and the dynamic torque on the servo motor is provided by a load motor on a common driveshaft.

Author

**N90-29878\*#** California Univ., Santa Barbara. Dept. of Mechanical Engineering.

**INVERSE DYNAMICS OF A 3 DEGREE OF FREEDOM SPATIAL FLEXIBLE MANIPULATOR**

EDUARDO BAYO and M. SERNA *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 31-40 31 Jan. 1989 Sponsored in part by NSF

(Contract NATO-0877-87)

Avail: NTIS HC A19/MF A03 CSCL 06/8

A technique is presented for solving the inverse dynamics and kinematics of 3 degree of freedom spatial flexible manipulator. The proposed method finds the joint torques necessary to produce a specified end effector motion. Since the inverse dynamic problem in elastic manipulators is closely coupled to the inverse kinematic problem, the solution of the first also renders the displacements and rotations at any point of the manipulator, including the joints. Furthermore the formulation is complete in the sense that it includes all the nonlinear terms due to the large rotation of the links. The Timoshenko beam theory is used to model the elastic characteristics, and the resulting equations of motion are discretized using the finite element method. An iterative solution scheme is proposed that relies on local linearization of the problem. The solution of each linearization is carried out in the frequency domain. The performance and capabilities of this technique are tested through simulation analysis. Results show the potential use of this method for the smooth motion control of space telerobots.

Author

**N90-29879\*#** Tulane Univ., New Orleans, LA. Dept. of Electrical Engineering.

**A CONTROL APPROACH FOR ROBOTS WITH FLEXIBLE LINKS AND RIGID END-EFFECTORS**

ENRIQUE BARBIERI and UMIT OZGUNER (Ohio State Univ., Columbus.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 41-50 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 06/8

Multiarm\_flexible\_robots\_with\_dexterous\_end\_effectors are currently being considered in such tasks as satellite retrieval, servicing and repair where a two phase problem can be identified: Phase 1, robot positioning in space; Phase 2, object retrieval. Some issues in Phase 1 regarding modelling and control strategies for a robotic system comprised of a long flexible arm and a rigid three-link end effector are presented. The control objective is to

maintain the last (rigid) link stationary in space in the presence of an additive disturbance caused by the flexible energy in the first link after a positioning maneuver has been accomplished. Several configuration strategies can be considered, and optimal decentralized servocompensators can be designed. Preliminary computer simulations are included for a simple proportional controller to illustrate the approach. Author

N90-29882\*# Lockheed Engineering and Management Services Co., Inc., Houston, TX.

**FLIGHT TELEROBOTIC SERVICER CONTROL FROM THE ORBITER**

TEXAS M. WARD and DON L. HARLAN /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 73-80 31 Jan. 1989

(Contract NAS9-17900)

Avail: NTIS HC A19/MF A03 CSCL 05/8

The research and work conducted on the development of a testbed for a display and control panel for the Flight Telerobotic Servicer (FTS) are presented. Research was conducted on both software and hardware needed to control the FTS. A breadboard was constructed and placed into a mockup of the aft station of the Orbiter spacecraft. This breadboard concept was then evaluated using a computer graphics representation of the Tinman FTS. Extensive research was conducted on the software requirements and implementation. The hardware selected for the breadboard was 'flight like' and in some cases fit and function evaluated. The breadboard team studied some of the concepts without pursuing in depth their impact on the Orbiter or other missions. Assumptions are made concerning payload integration.

Author

N90-29883\*# New York Univ., New York. Robotics Research Lab.

**TELEOPERATION EXPERIMENTS WITH A UTAH/MIT HAND AND A VPL DATAGLOVE**

D. CLARK, J. DEMMEL, J. HONG, GERARDO LAFFERRIERE, L. SALKIND, and X. TAN /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 81-89 31 Jan. 1989

(Contract NAG2-493; N00014-87-K-0129; CMU-406349-55586; NSF DCR-83-20085)

Avail: NTIS HC A19/MF A03 CSCL 05/8

A teleoperation system capable of controlling a Utah/MIT Dextrous Hand using a VPL DataGlove as a master is presented. Additionally the system is capable of running the dextrous hand in robotic (autonomous) mode as new programs are developed. The software and hardware architecture used is presented and the experiments performed are described. The communication and calibration issues involved are analyzed and applications to the analysis and development of automated dextrous manipulations are investigated. Author

N90-29887\*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

**THE TELEROBOT WORKSTATION TESTBED FOR THE SHUTTLE AFT FLIGHT DECK: A PROJECT PLAN FOR INTEGRATING HUMAN FACTORS INTO SYSTEM DESIGN**

TIMOTHY SAUERWEIN /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 121-130 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

The human factors design process in developing a shuttle orbiter aft flight deck workstation testbed is described. In developing an operator workstation to control various laboratory telerobots, strong elements of human factors engineering and ergonomics are integrated into the design process. The integration of human factors is performed by incorporating user feedback at key stages in the project life-cycle. An operator centered design approach helps insure the system users are working with the system designer in the design and operation of the system. The design methodology is presented along with the results of the design and the solutions regarding human factors design principles. Author

N90-29889\*# Sandia National Labs., Albuquerque, NM.

**AN ALTERNATIVE CONTROL STRUCTURE FOR TELEROBOTICS**

PETER T. BOISSIERE and RAYMOND W. HARRIGAN /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 141-150 31 Jan. 1989 Previously announced as N89-29751

(Contract DE-AC04-76DP-00789)

Avail: NTIS HC A19/MF A03 CSCL 05/8

A new teletrobotic control concept which couples human supervisory commands with computer reasoning is presented. The control system is responsive and accomplishes an operator's commands while providing obstacle avoidance and stable controlled interactions with the environment in the presence of communication time delays. This provides a system which not only assists the operator in accomplishing tasks but modifies inappropriate operator commands which can result in safety hazards and/or equipment damage. Author

N90-29890\*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

**INTEGRATION OF A SENSOR BASED MULTIPLE ROBOT ENVIRONMENT FOR SPACE APPLICATIONS: THE JOHNSON SPACE CENTER TELEOPERATOR BRANCH ROBOTICS LABORATORY**

JAMES HWANG, PERRY CAMPBELL, MIKE ROSS (Lockheed Engineering and Management Services Co., Inc., Houston, TX.), CHARLES R. PRICE, and DON BARRON /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 151-160 31 Jan. 1989

(Contract NAS9-1900)

Avail: NTIS HC A19/MF A03 CSCL 05/8

An integrated operating environment was designed to incorporate three general purpose robots, sensors, and end effectors, including Force/Torque Sensors, Tactile Array sensors, Tactile force sensors, and Force-sensing grippers. The design and implementation of: (1) the teleoperation of a general purpose PUMA robot; (2) an integrated sensor hardware/software system; (3) the force-sensing gripper control; (4) the host computer system for dual Robotic Research arms; and (5) the Ethernet integration are described. Author

N90-29893\*# Chicago Univ., IL. Dept. of Electrical Engineering and Computer Science.

**ON DISCRETE CONTROL OF NONLINEAR SYSTEMS WITH APPLICATIONS TO ROBOTICS**

MANSOUR ESLAMI /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 183-191 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

Much progress has been reported in the areas of modeling and control of nonlinear dynamic systems in a continuous-time framework. From implementation point of view, however, it is essential to study these nonlinear systems directly in a discrete setting that is amenable for interfacing with digital computers. But to develop discrete models and discrete controllers for a nonlinear system such as robot is a nontrivial task. Robot is also inherently a variable-inertia dynamic system involving additional complications. Not only the computer-oriented models of these systems must satisfy the usual requirements for such models, but these must also be compatible with the inherent capabilities of computers and must preserve the fundamental physical characteristics of continuous-time systems such as the conservation of energy and/or momentum. Preliminary issues regarding discrete systems in general and discrete models of a typical industrial robot that is developed with full consideration of the principle of conservation of energy are presented. Some research on the pertinent tactile information processing is reviewed. Finally, system control methods and how to integrate these issues in order to complete the task of discrete control of a robot manipulator are also reviewed. Author

**N90-29895\***# National Aeronautics and Space Administration.  
Lyndon B. Johnson Space Center, Houston, TX.

**FLIGHT EXPERIMENTS IN TELEROBOTICS-ORBITER**

**MIDDECK CONCEPT**

LYLE M. JENKINS /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 207-213 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

Most uncertainties of operation of a telerobot in the space environment relate to the absence of gravity effects and not to the vacuum effects. A flight experiment concept is proposed for the middeck of the space shuttle that provides direct access for the crew. Telerobot dexterous manipulation issues in task performance, mechanism response, system duty cycles, and operator interface can be effectively addressed. A pair of replica-type master controllers would be adapted for slave manipulator functions. A variety of test setups and control modes can obtain data on zero G operation of a telerobot. Author

**N90-29897\***# Advanced Decision Systems, Mountain View, CA.  
**THE ASTRONAUT AND THE BANANA PEEL: AN EVA**

**RETRIEVER SCENARIO**

DANIEL G. SHAPIRO /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 225-234 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

To prepare for the problem of accidents in Space Station activities, the Extravehicular Activity Retriever (EVAR) robot is being constructed, whose purpose is to retrieve astronauts and tools that float free of the Space Station. Advanced Decision Systems is at the beginning of a project to develop research software capable of guiding EVAR through the retrieval process. This involves addressing problems in machine vision, dexterous manipulation, real time construction of programs via speech input, and reactive execution of plans despite the mishaps and unexpected conditions that arise in uncontrolled domains. The problem analysis phase of this work is presented. An EVAR scenario is used to elucidate major domain and technical problems. An overview of the technical approach to prototyping an EVAR system is also presented. Author

**N90-29898\***# Stanford Univ., CA. Aerospace Robotics Lab.  
**COMPUTED TORQUE CONTROL OF A FREE-FLYING**

**COOPERATING-ARM ROBOT**

ROSS KONINGSTEIN, MARC ULLMAN, and ROBERT H. CANNON, JR. /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 235-243 31 Jan. 1989

(Contract NCC2-333)

Avail: NTIS HC A19/MF A03 CSCL 05/8

The unified approach to solving free-floating space robot manipulator end-point control problems is presented using a control formulation based on an extension of computed torque. Once the desired end-point accelerations have been specified, the kinematic equations are used with momentum conservation equations to solve for the joint accelerations in any of the robot's possible configurations: fixed base or free-flying with open/closed chain grasp. The joint accelerations can then be used to calculate the arm control torques and internal forces using a recursive order N algorithm. Initial experimental verification of these techniques has been performed using a laboratory model of a two-armed space robot. This fully autonomous spacecraft system experiences the drag-free, zero G characteristics of space in two dimensions through the use of an air cushion support system. Results of these initial experiments are included which validate the correctness of the proposed methodology. The further problem of control in the large where not only the manipulator tip positions but the entire system consisting of base and arms must be controlled is also presented. The availability of a physical testbed has brought a keener insight into the subtleties of the problem at hand. Author

**N90-29899\***# Tsukuba Space Center (Japan).

**NEXT GENERATION SPACE ROBOT**

TSUTOMU IWATA, MITSUSHIGE ODA, and RYOICHI IMAI /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 245-252 31 Jan. 1989  
Avail: NTIS HC A19/MF A03 CSCL 05/8

The recent research effort on the next generation space robots is presented. The goals of this research are to develop the fundamental technologies and to acquire the design parameters of the next generation space robot. Visual sensing and perception, dexterous manipulation, man machine interface and artificial intelligence techniques such as task planning are identified as the key technologies. Author

**N90-29900\***# Drexel Univ., Philadelphia, PA. Dept. of Electrical and Computer Engineering.

**COORDINATION IN A HIERARCHICAL MULTI-ACTUATOR CONTROLLER**

ALEX MEYSTEL /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 255-262 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

A hierarchical multi-actuator controller is represented as a multi-resolutional information (knowledge) system utilizing a number of intelligent modules with decision making capabilities. The laws of multi-resolutional information (knowledge) organization and processing are presumed to be satisfied including the rules of dealing with redundant knowledge. A general case is considered in which a process to be controlled by a multiplicity of actuators is a distributed one and the condition of distribution can be formulated analytically. Operation of a lumped multi-actuator process is a particular case which has a broad practical application. Author

**N90-29901\***# Bureau of Mines, Pittsburgh, PA.

**DISTRIBUTED COMMUNICATIONS AND CONTROL NETWORK FOR ROBOTIC MINING**

WILLIAM H. SCHIFFBAUER /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 263-272 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

The application of robotics to coal mining machines is one approach pursued to increase productivity while providing enhanced safety for the coal miner. Toward that end, a network composed of microcontrollers, computers, expert systems, real time operating systems, and a variety of program languages are being integrated that will act as the backbone for intelligent machine operation. Actual mining machines, including a few customized ones, have been given telerobotic semiautonomous capabilities by applying the described network. Control devices, intelligent sensors and computers onboard these machines are showing promise of achieving improved mining productivity and safety benefits. Current research using these machines involves navigation, multiple machine interaction, machine diagnostics, mineral detection, and graphical machine representation. Guidance sensors and systems employed include: sonar, laser rangers, gyroscopes, magnetometers, clinometers, and accelerometers. Information on the network of hardware/software and its implementation on mining machines are presented. Anticipated coal production operations using the network are discussed. A parallelism is also drawn between the direction of present day underground coal mining research to how the lunar soil (regolith) may be mined. A conceptual lunar mining operation that employs a distributed communication and control network is detailed. Author

**N90-29903\***# Tecnospazio S.p.A., Milan (Italy).

**A COLLISION AVOIDANCE SYSTEM FOR A SPACEPLANE MANIPULATOR ARM**

ANNA SCIOMACHEN and PIERGIOVANNI MAGNANI /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 283-291 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

Part of the activity in the area of collision avoidance related to

the Hermes spaceplane is reported. A collision avoidance software system which was defined, developed and implemented in this project is presented. It computes the intersection between the solids representing the arm, the payload, and the objects. It is feasible with respect to the resources available on board, considering its performance. Author

**N90-29905\***# Institut National de Recherche d'Informatique et d'Automatique, Rennes (France).

### TEMPORAL LOGICS MEET TELEROBOTICS

ERIC RUTTEN and LIONEL MARCE /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 301-310 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

The specificity of telerobotics being the presence of a human operator, decision assistance tools are necessary for the operator, especially in hostile environments. In order to reduce execution hazards due to a degraded ability for quick and efficient recovery of unexpected dangerous situations, it is of importance to have the opportunity, amongst others, to simulate the possible consequences of a plan before its actual execution, in order to detect these problematic situations. Hence the idea of providing the operator with a simulator enabling him to verify the temporal and logical coherence of his plans. Therefore, the power of logical formalisms is used for representation and deduction purposes. Starting from the class of situations that are represented, a STRIPS (the STanford Research Institute Problem Solver)-like formalism and its underlying logic are adapted to the simulation of plans of actions in time. The choice of a temporal logic enables to build a world representation, on which the effects of plans, grouping actions into control structures, will be transcribed by the simulation, resulting in a verdict and information about the plan's coherence.

Author

**N90-29907\***# Centre National de la Recherche Scientifique, Toulouse (France).

### THE INDEXED TIME TABLE APPROACH FOR PLANNING AND ACTING

MALIK GHALLAB and AMINE MOUNIR ALAOUI /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 321-332 31 Jan. 1989 Sponsored in part by EEC and by French National Research Program

Avail: NTIS HC A19/MF A03 CSCL 05/8

A representation is discussed of symbolic temporal relations, called IxTeT, that is both powerful enough at the reasoning level for tasks such as plan generation, refinement and modification, and efficient enough for dealing with real time constraints in action monitoring and reactive planning. Such representation for dealing with time is needed in a teleoperated space robot. After a brief survey of known approaches, the proposed representation shows its computational efficiency for managing a large data base of temporal relations. Reactive planning with IxTeT is described and exemplified through the problem of mission planning and modification for a simple surveying satellite. Author

**N90-29908\***# Rochester Univ., NY. Dept. of Computer Science.

### REACTIVE BEHAVIOR, LEARNING, AND ANTICIPATION

STEVEN D. WHITEHEAD and DANA H. BALLARD /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 333-344 31 Jan. 1989  
(Contract NSF DCR-86-02958; R01-NS22407-01)

Avail: NTIS HC A19/MF A03 CSCL 05/8

Reactive systems always act, thinking only long enough to 'look up' the action to execute. Traditional planning systems think a lot, and act only after generating fairly precise plans. Each represents an endpoint on a spectrum. It is argued that primitive forms of reasoning, like anticipation, play an important role in reducing the cost of learning and that the decision to act or think should be based on the uncertainty associated with the utility of executing an action in a particular situation. An architecture for an adaptable reactive system is presented and it is shown how it

can be augmented with a simple anticipation mechanism that can substantially reduce the cost and time of learning. Author

**N90-29909\***# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

### SHUTTLE REMOTE MANIPULATOR SYSTEM MISSION PREPARATION AND OPERATIONS

ERNEST E. SMITH, JR. /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 347-351 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

The preflight planning, analysis, procedures development, and operations support for the Space Transportation System payload deployment and retrieval missions utilizing the Shuttle Remote Manipulator System are summarized. Analysis of the normal operational loads and failure induced loads and motion are factored into all procedures. Both the astronaut flight crews and the Mission Control Center flight control teams receive considerable training for standard and mission specific operations. The real time flight control team activities are described. Author

**N90-29910\***# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

### A COMPARISON OF THE SHUTTLE REMOTE MANIPULATOR SYSTEM AND THE SPACE STATION FREEDOM MOBILE SERVICING CENTER

EDITH C. TAYLOR and MICHAEL ROSS (Lockheed Engineering and Sciences Co., Houston, TX.) /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 353-361 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

The Shuttle Remote Manipulator System is a mature system which has successfully completed 18 flights. Its primary functional design driver was the capability to deploy and retrieve payloads from the Orbiter cargo bay. The Space Station Freedom Mobile Servicing Center is still in the requirements definition and early design stage. Its primary function design drivers are the capabilities: to support Space Station construction and assembly tasks; to provide external transportation about the Space Station; to provide handling capabilities for the Orbiter, free flyers, and payloads; to support attached payload servicing in the extravehicular environment; and to perform scheduled and un-scheduled maintenance on the Space Station. The differences between the two systems in the area of geometric configuration, mobility, sensor capabilities, control stations, control algorithms, handling performance, end effector dexterity, and fault tolerance are discussed.

Author

**N90-29911\***# Lockheed Engineering and Sciences Co., Houston, TX.

### DEXTEROUS MANIPULATOR FLIGHT DEMONSTRATION

EDWARD L. CARTER /n JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 363-372 31 Jan. 1989

Avail: NTIS HC A19/MF A03 CSCL 05/8

The Dexterous Manipulator Flight Experiment, an outgrowth of the Dexterous End Effector project, is an experiment to demonstrate newly developed equipment and methods that make for a dexterous manipulator which can be used on the Space Shuttle or other space missions. The goals of the project, the objectives of the flight experiment, the experiment equipment, and the tasks to be performed during the demonstration are discussed. Author

**N90-29913\***# Naval Weapons Center, China Lake, CA. Aircraft Weapons Integration Dept.

### MULTISENSOR EVALUATION FRAMEWORK Summary Report, May 1986 - Aug. 1989

DAVID C. FOYLE Sep. 1989 29 p  
(AD-A224271; AD-E900951; NWC-TP-7027) Avail: NTIS HC A03/MF A01 CSCL 17/11

Based on existing integration models in the literature, an evaluation framework is developed to assess the operator's ability to use multisensor, or sensor fusion, displays. GRA

**N90-29914#** International Atomic Energy Agency, Vienna (Austria).

**FACTORS AFFECTING PRACTICAL APPLICATION OF FOOD IRRADIATION**

Apr. 1990 88 p Presented at the Advisory Group Meeting on Commercial Use of Food Irradiation, Vienna, Austria, 27 Jun. 1988 Prepared in cooperation with Food and Agriculture Organization of the United Nations, Rome, Italy (DE90-631277; IAEA-TECDOC-544; CONF-8806477) Avail: NTIS (US Sales Only) HC A05/MF A01

An Advisory Group Meeting on Commercial Use of Food Irradiation was convened in order to discuss problems of the industry's acceptance of food irradiation and their remedies. Senior executives from major food industries, trade and consumer organizations were invited to discuss these problems and to prepare a report which would serve as the basis for a future plan of action by sponsoring organizations in the field of food irradiation. This publication contains the report of the meeting, papers presented by the participants and their recommendations to the sponsoring organizations. DOE

**N90-29915#** International Atomic Energy Agency, Vienna (Austria).

**HUMAN ERROR CLASSIFICATION AND DATA COLLECTION**

Jan. 1990 172 p Presented at the Technical Committee on Human Error Classification and Data Collection, Vienna, Austria, 20-24 Feb. 1989 (DE90-631408; IAEA-TECDOC-538; CONF-8902182) Avail: NTIS (US Sales Only) HC A08/MF A01

Analysis of human error data requires human error classification. As the human factors/reliability subject has developed, so too has the topic of human error classification. The classifications vary considerably depending on whether it has been developed from a theoretical psychological approach to understanding human behavior or error, or whether it has been based on an empirical practical approach. This latter approach is often adopted by nuclear power plants that need to make practical improvements as soon as possible. This document will review aspects of human error classification and data collection in order to show where potential improvements could be made. It will attempt to show why there are problems with human error classification and data collection schemes and that these problems will not be easy to resolve. The Annex of this document contains the papers presented at the meeting. A separate abstract was prepared for each of these 12 papers. DOE

**N90-29916#** Army Aeromedical Research Lab., Fort Rucker, AL. Biomedical Applications Div.

**VISUAL PROCESSING: IMPLICATIONS FOR HELMET MOUNTED DISPLAYS Report, Oct. 1989 - Apr. 1990**

JO L. CALDWELL, RHONDA L. CORNUM, ROBERT L. STEPHENS, and CLARENCE E. RASH May 1990 18 p Presented at the SPIE 1990 Technical Symposium on Aerospace Sensing, 16-20 Apr. 1990 Submitted for publication (AD-A223488; USAARL-90-11) Avail: NTIS HC A03/MF A01 CSCL 25/3

A study was conducted to compare the performance of AH-64 (Apache) pilots to other Army pilots on visual tasks. Each pilot was given a task presented monocularly to the right eye, a task presented monocularly to the left eye, and a task presented to both eyes simultaneously in a dichoptic task. Results indicated no performance difference between the groups of pilots on the dichoptic task, but indicated better performance on the left monocular task for the AH-64 pilots. These results indicate that AH-64 pilots who are required to switch their attention from their left eyes to their right eyes in order to obtain needed information are capable of processing information efficiently and effectively using only one eye. The implications of these results for the Integrated Helmet and Display Sighting System (IHADSS) are discussed. GRA

**N90-29917#** Sandia National Labs., Albuquerque, NM.

**OXYGEN DEFICIENCY MONITOR SYSTEM**

GARY L. DEVLIN (Ktech Corp., Albuquerque, NM.) 12 May

1990 24 p

(Contract DE-AC04-76DP-00789)

(DE90-014866; SAND-90-1955) Avail: NTIS HC A03/MF A01

This report describes the components and installation of the Oxygen Deficiency Monitor System (ODMS) at the Simulation Technology Laboratory (STL) at Sandia National Laboratories. The ODMS presently monitors the oxygen concentration of the ambient air in the lower levels of the laboratory where air circulation may be insufficient to disperse gases that may settle and accumulate creating an oxygen-deficient environment. The intent of this report is to provide a general introduction to the system for personnel involved in the maintenance and modifications of the system and may be useful to people interested in installing a similar system. This will report describe the hardware components, installation considerations, operation, and maintenance of the system. DOE

**N90-29918#** Bertin et Cie., Plaisir (France). Dept. Surete de Fonctionnement.

**PRELIMINARY HAZARD ANALYSIS IN DESIGN APPLICATION TO EVA SPACE SUIT**

T. BOUCON and R. CHASE (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands ) 1990 3 p In FRENCH; ENGLISH summary Presented at the 7th International Conference on Reliability and Maintainability, Brest, France, 18-23 Jun. 1990 (ETN-90-97585) Avail: NTIS HC A01/MF A01

The method developed for the analysis of hazards during the design steps of a system is described. The method takes into account material and human risks. An application example concerning the Extra Vehicular Activity (EVA) suit is presented. The results of the analysis, the hazard scenarios and recommendations are included. ESA

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### SPACE BIOLOGY

Includes exobiology; planetary biology; and extraterrestrial life.

**N90-29085\*#** Institute for Circadian Physiology, Boston, MA. **FLUID AND ELECTROLYTE HOMEOSTASIS DURING SPACEFLIGHT: ELUCIDATION OF MECHANISMS IN A PRIMATE**

SUSANNE CHURCHILL Apr. 1990 93 p

(Contract NAS2-10547)

(NASA-CR-177548; A-90095; NAS 1.26:177548) Avail: NTIS HC A05/MF A01 CSCL 06/3

Although it is now well accepted that exposure to the hypogravitic environment of space induces a shift of fluid from the lower extremities toward the upper body, the actual physiological responses to this central volume expansion have not been well characterized. Because it is likely that the fluid and electrolyte response to hypogravity plays a critical role in the development of Cardiovascular Deconditioning, elucidation of these mechanisms is of critical importance. The goal of flight experiment 223, scheduled to fly on SLS-2, is the definition of the basic renal, fluid and electrolyte response to spaceflight in four instrumented squirrel monkeys. The studies were those required to support the development of flight hardware and optimal inflight procedures, and to evaluate a ground-based model for weightlessness, lower body positive pressure (LBPP). Author

**N90-29086\*#** Tennessee Univ., Knoxville.

**REGULATION OF ERYTHROPOIESIS IN RATS DURING SPACE FLIGHT**

ROBERT D. LANGE Oct. 1989 26 p

(Contract NAS2-11586)

(NASA-CR-177537; NAS 1.26:177537) Copyright Avail: NTIS HC A03/MF A01 CSCL 06/3

Astronauts who have flown in microgravity have experienced a

## 55 SPACE BIOLOGY

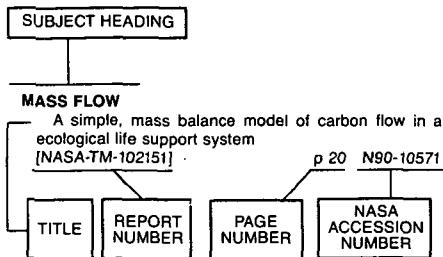
loss in red cell mass. The pathogenesis of the anemia of space flight has not been ascertained, but it is probably multifactorial. In 1978, the laboratory was selected to participate in life sciences studies to be carried out in the space shuttle in an attempt to study the pathogenesis of space anemia. In particular, the original studies were to be made in mice. This was later changed to study erythropoiesis in rats during space flight. Author

# SUBJECT INDEX

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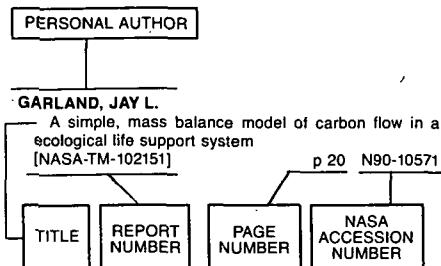
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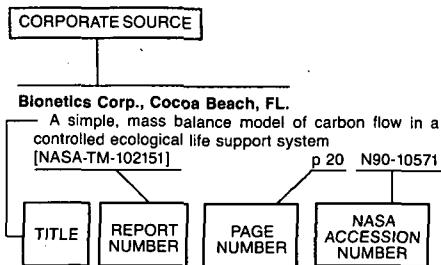
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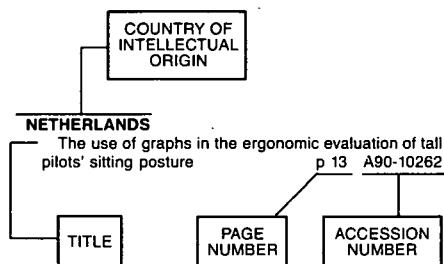
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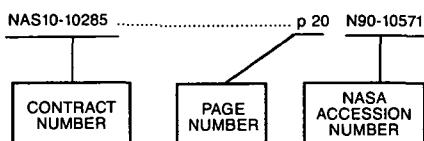
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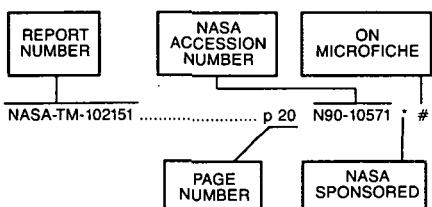
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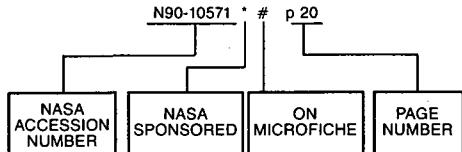
REPORT

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200 NE 18th Street  
Oklahoma City, OK 73105  
(405) 521-2502, ext. 252

## OKLAHOMA STATE UNIV. LIB.

Documents Department  
Stillwater, OK 74078  
(405) 624-0489

## OREGON

### PORTLAND STATE UNIV.

Millar Library  
934 SW Harrison - P.O. Box 1151  
Portland, OR 97207  
(503) 229-3673

## PENNSYLVANIA

### STATE LIBRARY OF PENN.

Government Publications Section  
Box 1601  
Walnut St. & Commonwealth Ave.  
Harrisburg, PA 17105  
(717) 787-3752

## SOUTH CAROLINA

### CLEMSON UNIV. COOPER LIB.

Documents Department  
Clemson, SC 29634  
(803) 656-5174  
In cooperation with Univ. of South Carolina, Thomas Cooper Library, Columbia

## TEXAS

### TEXAS STATE LIBRARY

Public Services Department  
P.O. Box 12927 - 1201 Brazos  
Austin, TX 78711  
(512) 463-5455

## TEXAS TECH. UNIV. LIBRARY

Documents Department  
Lubbock, TX 79409  
(806) 742-2268

## UTAH

### UTAH STATE UNIVERSITY

Merrill Library & Learning Resources Center, UMC-30  
Documents Department  
Logan, UT 84322  
(801) 750-2682

## VIRGINIA

### UNIVERSITY OF VIRGINIA

Alderman Library  
Government Documents  
Charlottesville, VA 22903  
(804) 924-3133

## WASHINGTON

### WASHINGTON STATE LIBRARY

Document Section  
Olympia, WA 98504  
(206) 753-4027

## WEST VIRGINIA

### WEST VIRGINIA UNIV. LIB.

Government Documents Section  
P.O. Box 6069  
Morgantown, WV 26506  
(304) 293-3640

## WISCONSIN

### ST. HIST SOC. OF WISCONSIN LIB.

Government Pub. Section  
816 State Street  
Madison, WI 53706  
(608) 262-2781  
In cooperation with Univ. of Wisconsin-Madison, Memorial Library

## MILWAUKEE PUBLIC LIBRARY

Documents Division  
814 West Wisconsin Avenue  
Milwaukee, WI 53233  
(414) 278-3065

## WYOMING

### WYOMING STATE LIBRARY

Supreme Court & Library Bldg.  
Cheyenne, WY 82002  
(307) 777-5919

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