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*There have been many amateur stations shown in QST which have been described by amateurs as being "out of this world." The Oscar beacon satellite, however, is the first one literally to make the grade! This paper is a review of the design and construction of this unit, touching briefly on the nature of some of the problems involved in building equipment that must operate in a space environment.*

# The Oscar Satellite

BY HARLEY GABRIELSON,* W6HEK

THE design objective of the Oscar program was to produce a package that would withstand the rigors of vehicle launch and that would work properly in the environment of space. The broad requirements called for equipment capable of radiating a 2-meter signal from orbit some 300 miles above the earth. This signal required a simple identifier, and it had to be capable of being heard and tracked by amateurs using relatively unsophisticated receiving equipment. A 140-milliwatt, crystal-controlled, c.w. transmitter, suitably keyed, and having an operating life of about three weeks, met these requirements.

Anticipating that the Discoverer vehicle was a likely source of launch into space, the packaging requirements for inclusion in this rocket were determined and were found to limit the equipment to a maximum weight of ten pounds contained within a rectangular-shaped configuration, curved to fit the outer circumference of the vehicle (Fig. 1).

### *The Reliability Problem*

The most important consideration in building a suitable space-radio beacon was reliability. Construction of Oscar involved much more than simply whipping up a 140-milliwatt transmitter and keyer, and then providing a set of batteries ample to run it for a few weeks. Oscar must be physically rugged enough to withstand the rigors of a rocket launch, following which it must operate normally without the benefit of retuning or "knob tweaking." All this must be accomplished with the end in view that the equipment will be operating in a rather unusual environment — the utter cold and stillness of outer space!

It is not sufficient to use the best components and the most rugged and conservative design — although these are necessary and vital ingredients to ultimate success. In addition, it is necessary to prove the reliability of the design by subjecting the complete equipment package to punishment in the laboratory under conditions as strenuous as the worst to be expected in actual operation. It must be emphasized that the launch of any satellite is an "all or nothing" operation. There is no chance to call the rocket back to correct some defect observed after the launch has taken place! This sober thought remained uppermost in the minds of the Oscar crew responsible for the design and testing of the package. Failure of the equipment after launch meant that many thousands of man-hours of work, plus the hopes and dreams of the Oscar volunteers, would be to no avail. It also meant that valuable space in the launching vehicle would go to waste, and time and effort spent by others assisting this venture would

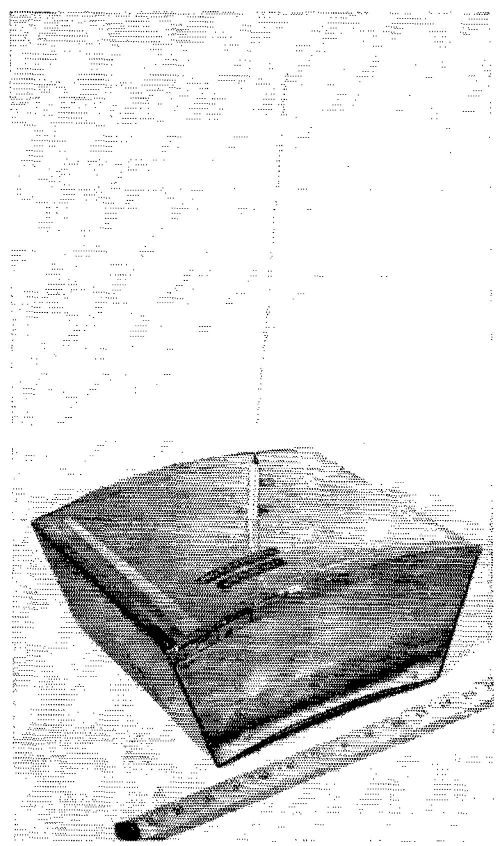

Fig. 1—Mock-up of the Oscar satellite used for preliminary design tests. The container is rectangular in shape and curved to fit the outer circumference of the launching vehicle. Final version of Oscar was gold-plated and had black strips across case to regulate internal temperature of package.

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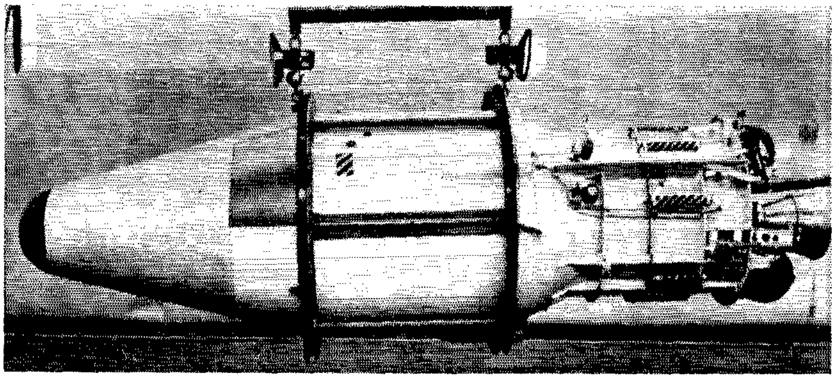

Fig. 2—The Agena-B satellite, "mother ship" for Oscar. Used in the Discoverer program, the Agena-B tips the scales at more than 8500 pounds when it is boosted space-ward by the Thor IRBM vehicle. In orbit, Agena weighs about 1700 pounds after the liquid propellant has been exhausted. The Oscar satellite was placed in the aft equipment rack (extreme right in photograph). Once in orbit, the "piggy-back" Oscar beacon was ejected from the Agena, to go into its own orbit about the earth. Nose cone of Discoverer XXXVI was recovered in Pacific area after four days of orbiting about the earth, while Oscar continued on his journey alone!

have passed for naught. It was imperative, therefore, that every possible step be taken to make sure that Oscar would work once it had been blasted into the reaches of space. The Association, in addition, had to demonstrate to the launching agency that the equipment would meet the demands placed upon it, yet at the same time would not jeopardize the primary objectives of the launching vehicle. Further, it must be demonstrated that the Oscar equipment would have a high probability of performing correctly once it reached orbit.

### *The Oscar Package*

The first design problem of any satellite package concerns the matter of the container in which the equipment is to travel. The housing must hold things together, and this is no mean task during the acceleration phase of the launch. In addition, the container must provide the proper temperature environment for the electronic components while they are whirling about in orbit. During the period the satellite is between the earth and the sun, the container is directly exposed to radiation from the sun without the benefit of protection from the atmosphere. On the other hand, for something less than half of the time the container will be hidden in the shadow of the earth and will be radiating its heat into the cold blackness of space. (The heat generated within the container by the equipment will have a negligible effect on the over-all heat balance.) The problem, therefore, is to cause the package to absorb the same amount of heat during the period it is exposed to sunlight as it loses by radiation during the time the satellite is hidden behind the earth. In this way, an average internal temperature can be maintained, well within the limits that the electronic components can withstand.

The heat balance of the Oscar package has been established by plating the surface of the container with gold to reflect most of the incident heat from the sun and then canceling part of the reflection by covering a portion of the gold surface with a pattern of absorptive paint which will absorb just the desired amount of heat to maintain the proper temperature balance.

This system of heat balance will establish an average temperature, but the day-to-night variations will be quite extreme unless a further precaution is taken. The electronic equipment in the Oscar package is protected by a thick coating of epoxy foam. The foam coating accomplishes two important functions: First, it helps strengthen the equipment by holding the components firmly in place. Second, the foam serves as a heat insulator which inhibits the transfer of heat into and out of the electronic gear. As a result, the internal temperature of Oscar will average out the extremes seen at the surface of the container. The final evaluation of this design feature will be obtained when the "HI" rate reports are reduced to equipment-temperature readings.

The Oscar container is made of a magnesium alloy to hold weight to a minimum and measures approximately 12 by 14 by 6 inches in size. It is curved to conform to the circumference of the Agena satellite. When the Agena achieves orbit, the "piggy-back" Oscar package is ejected upon command. An adapter fitting is rigidly attached to the Agena in the aft-equipment rack near the motor housing (Fig. 2). The Oscar satellite is fastened into this adapter and held in place with an explosive bolt holding an ejection spring under compression. Upon receipt of the ejection command the bolt is released by a pin-puller, permitting the spring to eject the ham satellite from the parent vehicle at a speed of about 5 feet per second (3 miles per hour). As there is no air resistance to slow it down, the Oscar satellite will continue to separate from the carrier satellite at this rate indefinitely. At the time of separation, a latch is released which allows the antenna to spring upright into operating position. Dual snap-switches actuated by the release mechanism turn on the operating power to the 145-Mc. transmitter and Oscar is on the air!

### *The OSCAR Transmitter*

In the interest of obtaining high primary-power efficiency, light weight and small volume, the Oscar transmitter is transistorized and is constructed upon a set of glass-epoxy printed wiring boards. This method of assembly provides the physical ruggedness and electrical stability required for the extreme environments which Oscar encounters. The r.f. and keyer assemblies are built as separate modules (Figs. 3 and 4). Modular construction makes it possible to use the functional units in later phases of the Oscar program, and also improves the flexibility of installation in the event that the container shape is changed at the last moment.

### *The R.F. Section*

The r.f. unit, Fig. 5, consists of a 2N1493 crystal-controlled oscillator operating on the fifth overtone of the crystal to produce a 72.5-Mc. signal source. The signal is amplified by a 2N1506 buffer stage which is base-driven. The r.f. level of the buffer stage output is about 180 milliwatts. A Varicap diode doubler stage ($VC_1$) delivers approximately 140 milliwatts at 145 Mc. The output tank circuit is tapped at the proper point to provide a match to the 50-ohm coaxial line which feeds the antenna.

Curiously enough, one of the problems encountered during the development of the transmitter was that of too much power output! A fine balance had to be achieved between power output and primary battery life. Too much output meant that battery life would be unreasonably short. In the final unit, the over-all transmitter efficiency is better than 30 per cent at a power output level of 140 milliwatts. This balance permits good battery life, yet allows a good signal to be radiated.

### *The Keyer Section*

A unique, recognizable identification was required for the Oscar satellite. A waiver was obtained from the FCC so that the Oscar call, W6EE, need not be transmitted. The symbols "HI" were chosen as the identifier as they are relatively easy to generate, because they have a low duty cycle, and because they are easily recognized on the air (even by phone men!). Last—but by no means least — the greeting "HI" is internationally recognized as a friendly salutation among amateurs. From the design standpoint, the important factor is that "HI" has a low duty cycle — that is, the time-off is large in comparison to the time-on, which helps minimize the average power drain of the transmitter r.f. section.

The transmitter keyer makes use of digital circuits which may not be familiar to many amateurs. Space does not permit a detailed description of the keyer in the present article, but the circuits in general are similar to those that have been used in electronic keyers. (For those readers who wish to pursue this fascinating subject further, the Navy publication, *A Handbook of Selected Semiconductor Circuits,*[1] should prove to be very interesting.)

### *The Antenna*

A nondirectional antenna pattern is desired because the orbiting package will not be stabilized and quite likely will be tumbling as it revolves about the earth. But while it would be possible to generate a nondirectional radiation pattern, such a requirement would impose additional undesirable weight and complexity upon the Oscar package. For this reason, a simple ground-plane antenna is used. A quarter-wave monopole operates against the metal case of Oscar which (after a fashion) serves as the other half of the dipole. The resulting pattern, Fig. 6, is similar to that of a half-wave dipole in space. Here is one situation where the free-space pattern of an antenna is utilized in practice!

It would have been desirable if the deep nulls of the pattern could have been eliminated; however, they should have little detrimental effect upon signal reception. In fact, the roll rate of the package may be determined from the ampli-

[1] U.S. Government Printing Office, Washington, 25, D.C. BuShips NObsr 73231, NAVships 93484, price $2.25.

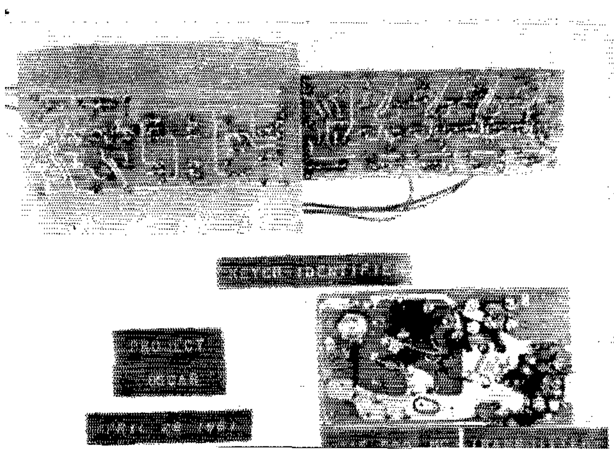

**Fig. 3—Bottom view of Oscar printed-circuit boards. The electrical connections between circuit components are made by means of thin copper plated to the insulating board.**

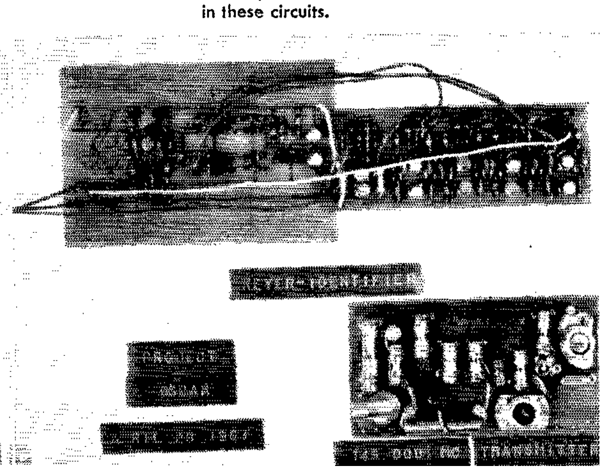

**Fig. 4—The Oscar unit is built upon two printed-circuit boards. At top is the keyer and pulse-generator unit. The 145-Mc. transmitter is below. Sixteen transistors, a number of diodes and a "Varicap" semiconductor are used in these circuits.**

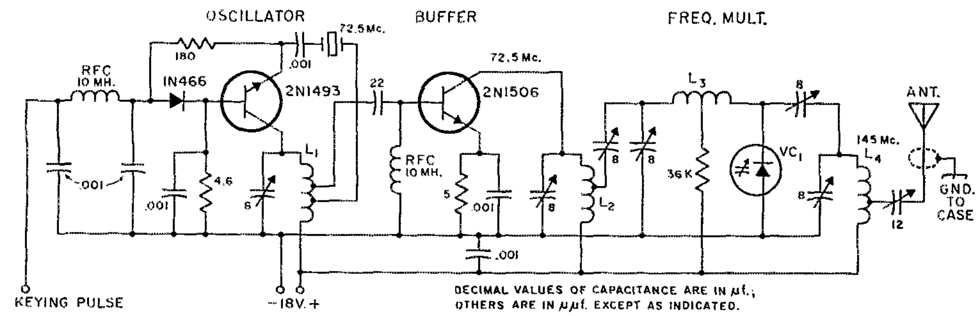


**Fig. 5—The Oscar transmitter circuit. Tuning capacitors are 8-μμf. trimmers. R.f. coils are wound with No. 22 tinned wire on nylon forms, 0.2-inch diameter, threaded 20 turns per inch.**

**$L_1$—9 turns, tapped at 3 and 6½ turns.**
**$L_2$—9 turns center-tapped.**
**$L_3$—31 turns center-tapped.**
**$L_4$—7 turns, tapped at 2¾ turns.**
**$VC_1$—Variable-capacitance diode (Pacific semiconductors 115-10).**

tude modulation of the signal produced by the rotation in space of the nulls. The antenna is held closely against the package during launch, but springs into a vertical position when Oscar is flung into separate orbit.

### *The Power Supply*

During the preliminary study of the configuration, it was decided that small internal batteries would be sufficient to provide power for the beacon for three- to four-week operation at the 140-milliwatt power level. Characteristics demanded of batteries to be used in space application include the following: high power output per pound of weight, operation in any position, insensitive to temperature extremes, low electrical leakage, nonexplosive in event of failure, and capable of being used in a high-vacuum environment. Mercury cells similar to those used in the Vanguard satellite were selected to power the unit. Three 18-volt batteries were connected in parallel to meet the capacity requirement. Each battery is protected against reverse current by a series diode should one of the batteries fail in service. Two of the three batteries are sufficient to power the equipment for 30 days under normal operating conditions, giving a total transmitter life of about 45 days under ideal conditions. Debited against the total life must be the time consumed during pre-launch check-outs, leakage loss during the waiting period after assembly, and drop in efficiency of the cells at low temperatures. At the end of battery life, the voltage drops rapidly to the point where the equipment will cease operating. This serves as an automatic "turn-off" switch after the designed operating life of approximately 28 days has elapsed.

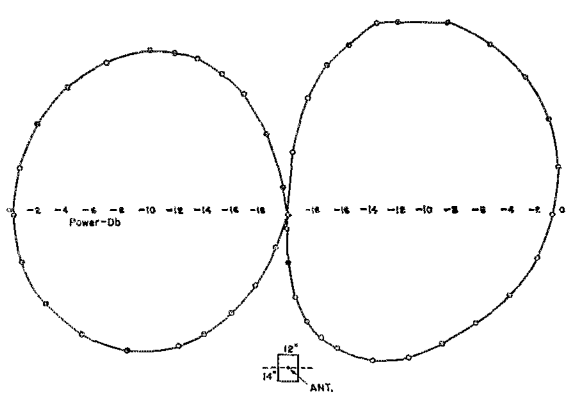


**Fig. 6—Polar plot of Oscar radiation pattern with the container in vertical position, whip in horizontal plane. Plot in horizontal plane is a circle.**

### *Testing the Oscar Beacon*

Once the average amateur completes the construction of a piece of gear, he gives it a quick once-over to see that nothing looks amiss, then he turns on the power for the proverbial "smoke test." For a unit designed for operation in outer space, such a test is just a good beginning! For example, the operational tests must be much more thorough to insure that the unit is performing as intended, as once in the launching vehicle there is no means to realign *this*, or adjust *that!* Normal operational tests for the Oscar beacon include: D.c. power input level, r.f. power output, keying rate and proper code formation. These measurements are made during the environmental testing.

To insure that the unit will operate when it reaches orbit, the equipment is subjected to test conditions that are comparable to those expected in normal operation. These conditions include temperature extremes of 0 to +150 degrees F. (−35 degrees to +65 degrees C.), shock (50G, maximum), acceleration (15G, maximum), vibration (15G, maximum), and altitude (over 200,000 feet).

The detailed specifications required for the environmental testing of the Oscar payload were written by Nick Marshall, W6OLO. Suffice to say, these tests were passed with flying colors by the Oscar beacon. Laboratory equipment necessary to conduct these tests was utilized over week-end periods at some of the electronic laboratories located in the immediate area. Other items of test equipment were homemade, and their construction and use would be a story in itself.

(*Continued on page 152*)

faster and faster . . . the track of flame marks its progress into the heavens . . . the program control starts to tilt the vehicle in the proper direction out over the Pacific Ocean . . . the teletype could once again be heard tapping out history. . . .

. . . GOING UP. . . . LOOKS GOOD. . . . STILL CLIMBING. . . . ON COURSE. . . . ON AZIMUTH. . . . ON COURSE. . . .

And so, on December 12, 1961, at 2042 GMT, Discoverer XXXVI was launched into orbit, carrying into separate orbit Oscar I guided in its flight into history by the thoughts and prayers of thousands of radio amateurs who stand on the threshold of tomorrow. QST

## Oscar Satellite

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### *Kudos*

The work performed in the development, construction and testing of the Oscar beacon was the result of the cooperative efforts of a large number of radio amateurs and other interested persons working together on a voluntary basis. Nick Marshall, W6OLO, Project Oscar Technical Director, and Dick Esneault, W4IJC/6, Project Manager, made sure the project remained true to the original aim and supervised closely to a successful completion. Al Diem, W3LSZ/6, Project Engineer, designed the r.f. assembly and handled battery and encapsulation problems. Harry Hughes worked out the ideas and surmounted the problems of the code generator. Gail Gangwish and Doug Beck, WA6AAI, packaged the keyer assembly into launchable shape. The antenna work, including patterns, was done by C. A. Andrews, W6LHV, and Jim Daly. Wally Raven, WA6AID, and Jim Barnett were consultants on mounting and heating problems. Howard Linnenkohl, K6SSD, designed the container. Walt Read, W6ASH, got it built. Lance Ginner, K6FEJ, ran the injection tests. Jerre Crozier, W6IGE, handled the drafting and layout work. Chuck Smallhouse, WA6MGZ, Orv Dalton, K6UEY, and Herman Poole designed and built a second transmitter that served as a stand-by unit. Alf Modine, K6TWF, and Will Jensby wrote the test procedures.

There were gratis contributions of hard-to-obtain materials and services by local industries who had their spirit of adventure stirred by the project. Components, materials, laboratory and testing facilities were made available by Philco Corporation, Western Development Laboratories, Palo Alto, Calif., and by Lockheed Missiles and Space Co., El Monte, Calif. Transistors were contributed by Fairchild Transistor Co., Mountain View, Calif., Philco Corp., Radio Corporation of America, Diodes, Inc., and Pacific Semiconductors, Inc. Crystals were provided by X-tron, Inc., Oakland, Calif.; and Midland Crystals, Kansas City, Kansas; mercury batteries were supplied by Burgess Battery Co.

Countless other firms and individuals contrib-

*(Continued on page 134)*

uted suggestions and support to this unique project. To all of them, the Oscar Association extends its sincere thanks and points with pride to the results of this heartwarming amateur radio experiment: the "III" of Oscar as it circles the globe! QST

## Hurricane Carla

(*Continued from page 74*)

when found, he'd report same and get someone to stay there until a repair truck arrived, while he went looking for more. He also made the rounds of several shelters to keep the gang informed of developments. W5QKF operated over 50 hours without rest. W5FJ devoted over 48 hours conducting communications in and out of Houston on 40 meters. K5HZR and K5BWN spent many a long hour in the 7290 kc. Phone Net handling emergency traffic. K5CRJ in LaMarque did a remarkable job for the Texas City and Galveston area.

And so the story goes, a continuous tale of exploits of an amateur here, a group of amateurs there, RACES and AREC organizations performing what they have trained themselves to do, untrained operators springing to the task and often showing remarkable adaptability to the emergency situation. We want to mention all the amateurs who participated that we can [9], and we'd like to mention every individual's and group's contribution in detail, but space does not permit us to cover them all. Nevertheless, let the story of Carla go down in the annals of amateur radio as one of the finest contributions of the fraternity to the public necessity QST

[9] The following were not mentioned above, but were listed as active in emergency communications activity during Carla: *W5s* AEQ AUD AUM AYX APH AYH BAA BBV BJB BMB BKH BZN BZV CMF CKO CPP CWS DYR DIE DGJ DLC DON DQT DNE DJD DJC EPC EML EFH FNW FPJ GQJ GQE GY GOS GEL HKJ HGG IYF IAQ IVC JHW JNE JQN JSU JFU KSQ LR LZA LRI MIS MRY MIF MIN MPH MWH NHB NKZ OCN OX OWA PBA PDR PTP PEV QFQ QFH QJS QQU RIN RPH RVY RFC RWS SHD SNW TFH TIJ TBT UV UMZ USA UMC UFH URN UVO VWE VCE VCA WGQ WYK YHO YVU YCK YIU ZIH ZTB, *K5s* AEC ANK AEY AMK ANS AON AFN BVH BEQ BHF BLW BHP BQG BIT BAH BPH BWN CAN CEG CIS CAD DNE DCC DIM DJD EKJ EKO EPL EKN EFH EYZ FYG FPJ FYE FEZ FWQ FDU FTT GIY GJQ GHS GCW GZT GTZ HDX HXR HUA HHD HMF HTM HQU HVI IEN IBG INH ISH INK ITA IUY JFM JBQ KJK KEI KZQ KYN LLM LGB LTK LUG LXQ MWF MFA MVK MFS MJA MRY MMV NAS OLJ OIT OME OKA OVO PEQ PLH PKY PEI PUW PFC RDP RBM ROH RQI RKM SCT SLH SRO SXQ SMW SFR TOL TSL TCV TKY TAW UYU UWK UHF UAD VDD VIY VLW VQY VZM VUY VGY VHH WWE WYJ WFS WMS WXS W1U WVU WJB YLU YSI ZZI ZSE, *K2s* EIU QHH, *K3s* IJS NNC, *W4s* SQV PXN ATF, *K4s* ENW AVM GXW GRO HMC OAZ, W6MLZ, *W7s* GVS CRO MES, K7LRV, *WØs* PAM NYF, KØQOA.

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