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This document analyses the expected SPICE system RF radiation exposure levels.

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1 Executive Summary

This document presents the radio frequency exposure analysis results of the Littlefeet SPICE product. The analysis focused on independently calculating radio frequency exposure levels for each unit in the two-unit SPICE system. Each unit is capable of transmitting four GSM RF channels and one integrated modem GSM RF channel. Each unit was analyzed under maximum output power (worst-case) scenarios. This approach ensures FCC compliance under all operating conditions.

The FCC Maximum Permissible Exposure (MPE) regulation specifies two exposure criteria for occupational and general population limits. More specifically, occupational limit is 50 W/m^2 and general population limit is 10 W/m^2 . Each of these exposure power density limits is expressed for specified exposure durations. Occupational and general population exposure at these power densities is specified at durations of 6 minutes and 30 minutes respectively.

The calculations performed by Littlefeet determined the FCC compliance distance for FCC Maximum Permissible Exposure (MPE). Calculation results indicate bSPICE compliance for occupational and general population is 0.57 m and 1.27 m respectively. Calculation results indicate cSPICE compliance for occupational and general population is 0.19 m and 0.43 m respectively.

2 Abbreviations

SPICE	Small Profile Intelligent Coverage Element
BCCH	Broadcast Control Channel
RBS	Base Transceiver Station
GSM	Global System for Mobile Communications
ANSI	American National Standards Institute
RF	Radio Frequency
PCS	Personal Communication System
BSPICE	Littlefeet Base SPICE Unit
CSPICE	Littlefeet Coverage SPICE Unit

3 Objective

The objective of this document is to present calculated data for the electromagnetic radiation exposure levels in close proximity to the SPICE system RF emitting entities. The analysis will be restricted to the PCS spectrum.

4 Introduction

Concerns have been raised worldwide about the possibility of adverse health effects arising from exposure to RF radiation. RF radiation, as well as near ultraviolet radiation, visible light, infrared radiation and power frequency fields, are types of non-ionizing radiation. These, together with ionizing electromagnetic radiation (X-rays, gamma rays and higher frequency ultraviolet rays), make up the electromagnetic spectrum.

Ionizing radiation is of most concern, since it has the potential to destroy or alter human tissue and damage DNA. Non-ionizing radiation does not interact with human tissue in the same way as ionizing radiation. However, resonance interactions are possible with non-ionizing radiation. The depth of penetration and sites of absorption are dependent upon the wavelength of the energy. PCS frequencies (1.9 to 2 GHz) produce non-ionizing RF radiation.

Research has shown that the resonance interactions produced by RF radiation can only cause the molecules in biological material to vibrate and thereby generate heat. Efforts to determine whether RF radiation affects biological cells, other than through heat, are inconclusive.

It is obviously preferable to minimize the duration and magnitude of any RF radiation exposure for members of the general population, especially as there is still significant research being conducted throughout the world on other possible health risks associated with RF radiation exposure. This document addresses power density in terms of Maximum Permissible Exposure (MPE) for both Occupational/Controlled Exposure and General Population/Uncontrolled Exposure as described in the FCC Regulations. The SPICE system is a low power infrastructure solution for the wireless industry. The BSPICE and CSPICE are both low output power entities. The analysis performed in this document examines the expected RF radiation exposure levels as a function of distance for both the BSPICE and CSPICE entities.

This document supports FCC Form 731 specifically addressing the following ID and Equipment Codes:

- Grantee code: PFV
- Equipment Product Code CSPICE001 (CSPICE)
- Equipment Product Code BSPICE001 (BSPICE)
- Equipment Code: PCB Licensed Base Station For Part 24
- Frequency Translating Repeater System.

This document presents calculated data to support the FCC Application For Equipment Authorization. Supporting data pertains to radio frequency radiation exposure limits established by FCC. The FCC provides the specifications for radio frequency radiation exposure limits.

The following list indicates logical path for FCC RF hazard regulations:

Federal Communications Commission Rules and Regulations
Code of Federal Regulations
Title 47 - Telecommunication
Chapter 1 - federal Communications Commission
Subchapter B - Common Carrier Services
Part 24 - Personal Communications Services
Subpart C - Technical Standards
Sec. 24.52 RF hazards

Section 24.52 RF hazards provide further reference to Chapter 1 - Sec. 1.1307 (b), Sec. 2.1091, and Sec. 2.1093. Sections 2.1091 and 2.1093 relate to radio frequency radiation exposure evaluations: mobile devices and portable devices respectively and is not applicable to Littlefeet SPICE as a system. Section 1.1307 references section 1.1310 relating to human exposure to levels of radio frequency radiation.

In Section 1.1310 the FCC has adopted the recommendations based on National Council on Radiation Protection and Measurements (NCRP), and American National Standards Institute (ANSI). The FCC Limits for Maximum Permissible Exposure (MPE), generally derived from NCRP and ANSI, are presented in Table 1. This exposure level, based upon research to date, will not produce any adverse health effects.

	Power Density (mW/cm ²)	Power Density (W/m ²)	Time (minutes)
Occupational/Controlled	5.0	50.0	6
General Population/Uncontrolled	1.0	10.0	30

Table 1. FCC Maximum Permissible Exposure (MPE)

5 Prediction Method

The following formula is a conservative prediction (worst-case) of the far field power density of an electromagnetic energy source:

$$S = \text{EiRP} / (4\pi d^2)$$

Where:

S = power density

EiRP = equivalent (or effective) isotropic radiated power

D = distance to the center of radiation.

Power density is the effective power per unit area and decreases according to the “inverse square” law with distance.

To be even more conservative a 100% ground reflection can be added. This results in a doubling of the predicted field strength and a fourfold increase in power density. The revised formula is as follows:

$$S = \text{EiRP} / (\pi d^2)$$

This formula is generally applicable in the far field of the antenna, but it can be used to estimate a worst-case upper limit for far field equivalent power density in the near field of the antenna.

(Reference 6)

6 Power Density Comparisons

The GSM version of the SPICE system provides up to 4 RF channels per BSPICE and CSPICE. The GSM BCCH downlink channel is always active at full power. The remaining 3 channels are used intermittently as dictated by traffic needs. It is therefore only at specific times during the day that all 4 channels are likely to be active simultaneously. However, to maintain a conservative approach for the predictions, it will be assumed that the 4 channels are active at all times.

Each unit of the SPICE systems contains an integrated, single channel, wireless modem. The modem transmits only a few minutes per day to report health status, perform parameter modifications, and perform periodic network management tasks. To maintain a conservative approach in this analysis it is assumed that the single channel modem is active at all times.

This analysis presents calculated data for each SPICE unit as a system. More specifically, the data includes aggregated power from the four SPICE GSM BCCH/TCH channels and the integrated modem. This aggregated power is then considered as a single point source in the calculations of this document, thereby suggesting an amplified conservative calculation for power density at specified distances from the source in near field data. In reality the radiated power is distributed over the antenna surface area, which decreases the power density, by orders of magnitude compared to the point source taken in this analysis. This approach further makes the power density analysis more conservative (worst-case).

The antenna gain is another prediction variable. To simplify the prediction process, the conservative approach is to assume that the antenna gain is constant, at its maximum value, irrespective of the angle or distance between the test point and antenna. CSPICE Coverage antenna gain and modem antenna gain utilized in calculations are 8.0 dBi and 0.0 dBi respectively. BSPICE link antenna gain and modem antenna gain utilized in calculations are 16.0 dBi and 0.0 dBi respectively. It is important to note the bSPICE link antenna utilized in this calculation is a typical value. The bSPICE link antenna is not included in the Littlefeet SPICE product as a system. The customer supplies this link antenna. Based on the specific design requirements for the SPICE system the customer may opt for higher or lower gain antennas for the specific application. This analysis utilized 16.0 dBi in calculations as an industry standard for typical PCS deployments. Also, all antenna specifications utilized in the analysis are theoretical. Gain figures are those obtained from the vendor specifications.

Although two different integrated modem models were suggested in an earlier FCC submission, the SPICE unit will utilize only one of these modems. More specifically, the Omnipoint is specified for use. This modem has a maximum output power of 30 dBm. This maximum value is utilized in all calculations presented in this document.

Table 2 presents the input parameters used to model a BSPICE, CSPICE and conventional GSM Radio Base Station. Feeder losses have been neglected.

	BSPICE	CSPICE
Output Power per Carrier (dBm)	25	23
Antenna Gain (dBi)	16	8
EiRP per Carrier (dBm)	41	31
Composite EiRP (dBm) (4 carriers)	47	37
Modem EiRP (dBm)	30	30
Composite EiRP (W) (4 carriers + modem)	51.12	6.01

Table 2. Prediction Input Parameters

Note that the composite power is used in the prediction since it is the total RF energy absorbed by the human body that is of interest.

Table 3 presents the power density comparison as a function of distance. Distances corresponding to Maximum Permissible Exposure (MPE) of 50 W/m² for occupational and 10 W/m² for general public exposure are of particular interest.

Distance (m)	BSPICE (W/m²)	CSPICE (W/m²)
0.05	6508.64	765.46
0.1	1627.16	191.36
0.15	723.18	85.05
0.2	406.79	47.84
0.25	260.35	30.62
0.3	180.80	21.26
0.35	132.83	15.62
0.4	101.70	11.96
0.45	80.35	9.45
0.5	65.09	7.65
0.55	53.79	6.33
0.6	45.20	5.32
0.65	38.51	4.53
0.7	33.21	3.91
0.75	28.93	3.40
0.8	25.42	2.99
0.85	22.52	2.65
0.9	20.09	2.36
0.95	18.03	2.12
1	16.27	1.91
1.05	14.76	1.74
1.1	13.45	1.58
1.15	12.30	1.45
1.2	11.30	1.33
1.25	10.41	1.22
1.3	9.63	1.13
1.35	8.93	1.05
1.4	8.30	0.98
1.45	7.74	0.91
1.5	7.23	0.85

Table 3. Power Density, Calculated Results

Table 4 presents calculated data indicating the distance where FCC Sec. 1.1310 MPE limits are reached. These values are inclusive of 4 GSM channels and the integrated modem in simultaneous operation at maximum power.

SPICE Unit	Distance (meters)
BSPICE, Occupational	0.57
BSPICE, General Population	1.27
CSPICE, Occupational	0.19
CSPICE, General Population	0.43

Table 4. FCC 1.1310 MPE limit distances

Figure 1 graphically presents the BSPICE results from Table 3.

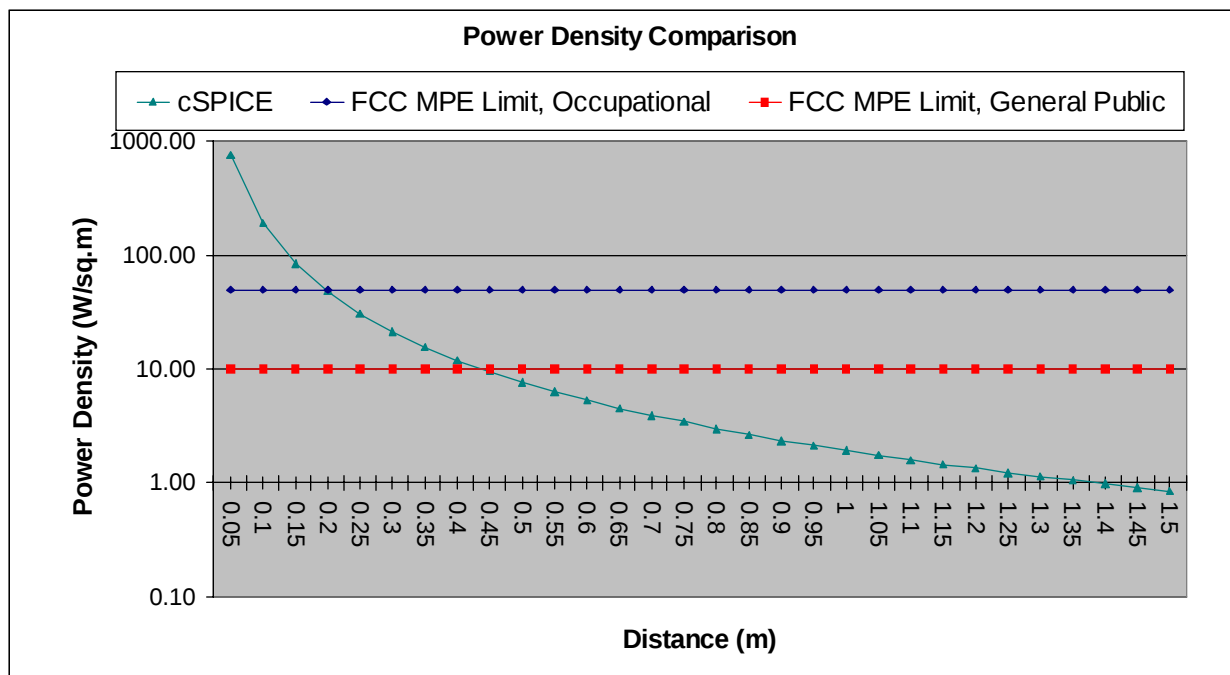


Figure 1. BSPICE Power Density

Figure 2 graphically presents the CSPICE results from Table 3.

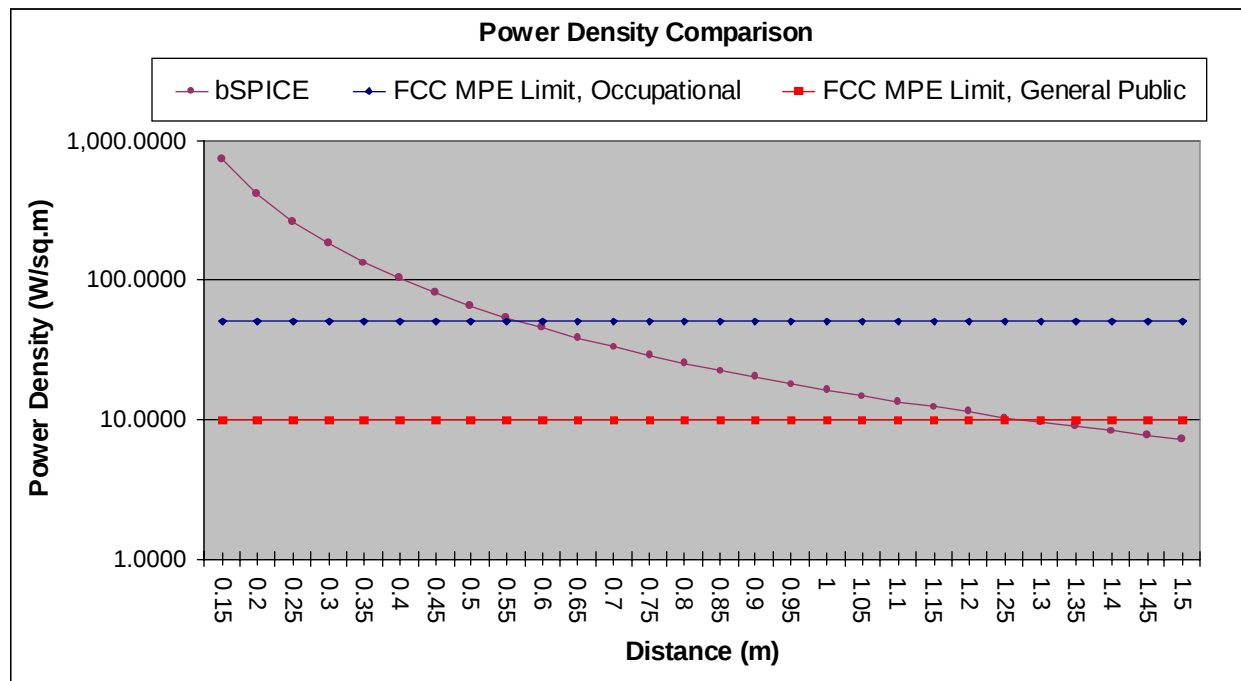


Figure 2. CSPICE Power Density

Table 5 presents the power density factors as a function of distance. This is simply a ratio of FCC MPE occupational power density limit to the calculated SPICE power density at a given distance. This table illustrates the orders of magnitude the FCC MPE safety limit is greater than what Littlefeet SPICE product generates.

Distance (m)	FCC Occupational Limit / BSPICE	FCC Occupational Limit / CSPICE
1	3.07	26.13
2	12.29	104.51
4	49.17	418.05
6	110.62	940.62
8	196.66	1672.21
10	307.28	2612.82
12	442.49	3762.47
14	602.28	5121.13
16	786.65	6688.83
18	995.60	8465.55
20	1229.14	10451.30
22	1487.25	12646.07
24	1769.96	15049.87
26	2077.24	17662.69
28	2409.11	20484.54
30	2765.56	23515.41

Table 5. Power Density Factors for Occupational

Table 6 presents the power density factors as a function of distance. This is simply a ratio of FCC MPE General population power density limit to the calculated SPICE power density at a given distance. This table illustrates the orders of magnitude greater the FCC MPE safety limit is than what Littlefeet SPICE product generates.

Distance (m)	FCC General Pop Limit / BSPICE	FCC General Pop Limit / CSPICE
1	0.61	5.23
2	2.46	20.90
4	9.83	83.61
6	22.12	188.12
8	39.33	334.44
10	61.46	522.56
12	88.50	752.49
14	120.46	1024.23
16	157.33	1337.77
18	199.12	1693.11
20	245.83	2090.26
22	297.45	2529.21
24	353.99	3009.97
26	415.45	3532.54
28	481.82	4096.91
30	553.11	4703.08

Table 6. Power Density Factors for General Population

Figure 3 presents the results from Table 5 graphically.

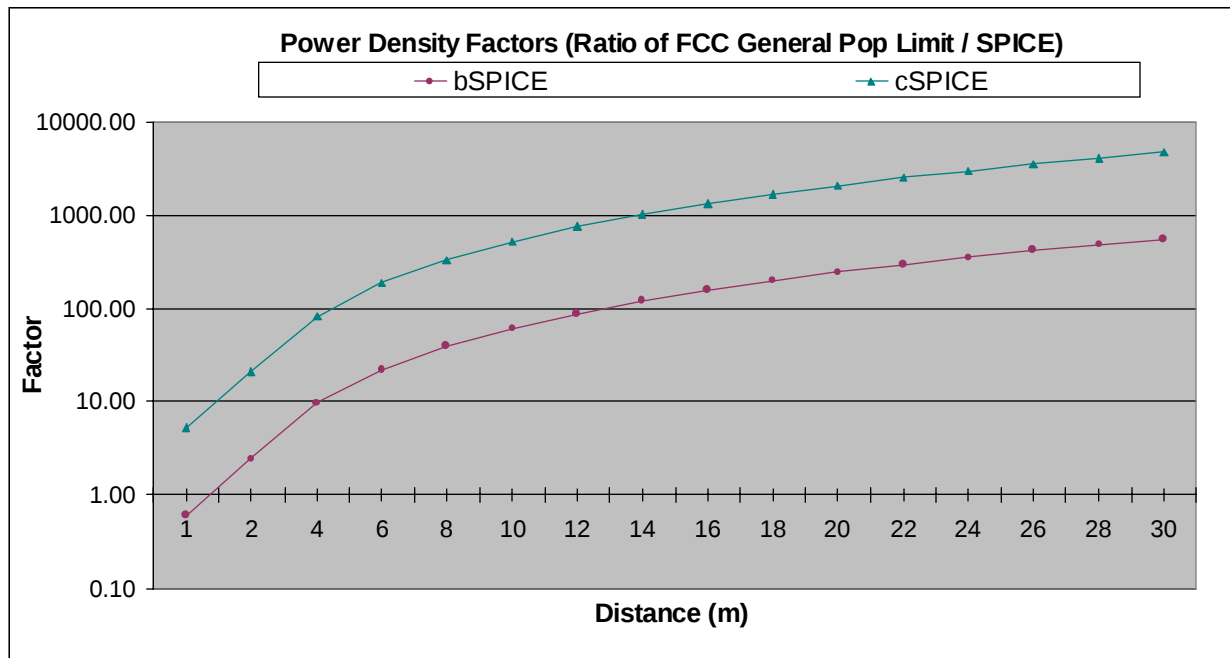


Figure 3. Power Density Factors for Occupational

Figure 4 presents the results from Table 6 graphically.

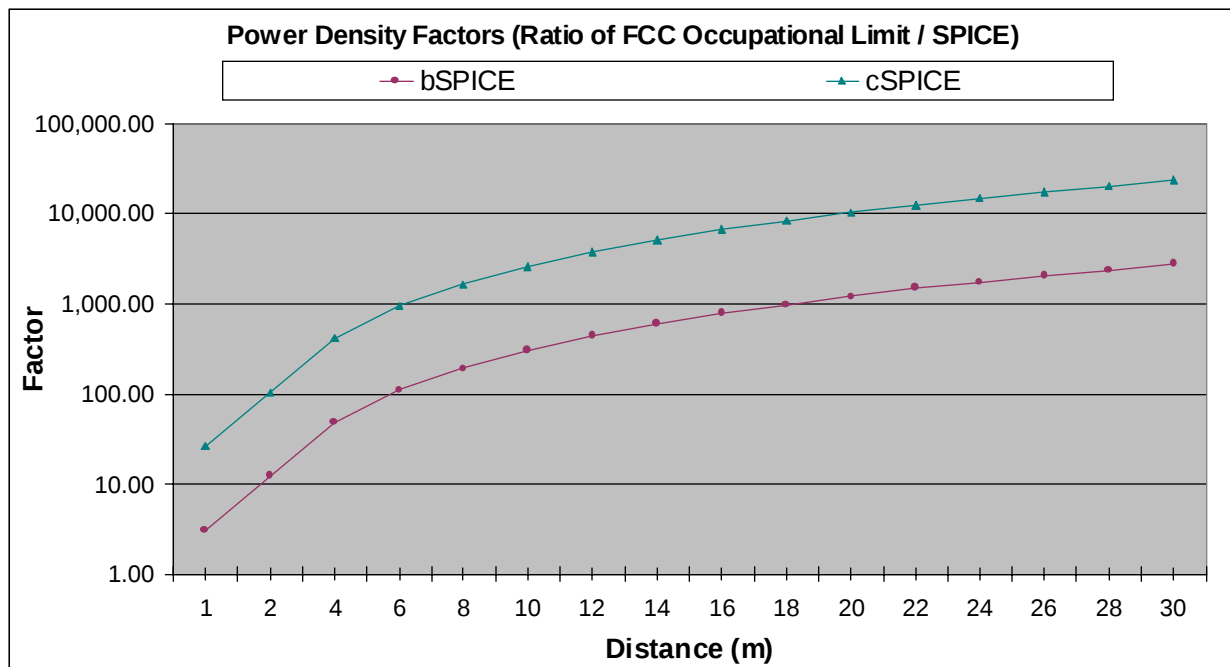


Figure 4. Power Density Factors for General Population

7 Discussion

The results of the power density comparison predictions are very encouraging, particularly given the highly conservative approach that was taken. The BSPICE and CSPICE exposure levels are many times lower than those for a conventional Radio Base Station. The results of this paper indicate the calculated MPE safe zone for each SPICE unit according to Table 10.

SPICE Unit	Distance (meters)
BSPICE, Occupational	0.57
BSPICE, General Population	1.27
CSPICE, Occupational	0.19
CSPICE, General Population	0.43

Table 10. Table 4. FCC 1.1310 MPE limit distances

The implementation scenarios for each SPICE product further secure the safety of both Occupational and General populations. The BSPICE transmit antenna is typically mounted not less than 30 meters off the ground. The CSPICE is typically mounted not less than 5 meters off the ground. The units are mounted on structures as close to freestanding as possible, free of obstacles, to maximize RF propagation. These distances further realize the negligible impact on people as the exposure experienced is orders of magnitude less than the FCC MPE limit, as described in Power Density Factors section of this documents. Had a more accurate analysis been undertaken, the RF radiation exposure levels would have been much lower for all components considered.

It is expected that neither SPICE unit radiating elements will be installed for operation in close proximity to people. This scenario would lead to poor RF propagation characteristics. Elevated positions are almost always preferred/required to acquire coverage to a greater area.

The data presented in this document are in close agreement with measurements performed by Hammett & Edison, Inc Consulting Engineers for MPE testing. The Hammett & Edison report was previously submitted to the FCC with FCC Form 731.

8 Conclusion

The results of the analysis performed in this document place the SPICE system in a commanding position for the wireless industry of today and the future. There is no way of knowing what researchers may find as they continue to investigate RF radiation, but should it be shown that there are adverse health effects, the SPICE system will be the ideal infrastructure solution due to its low power characteristics. The other possibility is that the output power of the BSPICE and CSPICE could be increased significantly without exceeding the RF radiation exposure levels generated by a conventional Radio Base Station.

9 References

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