Journal of Book of Mormon Studies

Volume 3 | Number 2 Article 1

7-31-1994

The Design of the Liahona and the Purpose of the Second Spindle

Robert L. Bunker
Observational Systems Division, JPL

Title The Design of the Liahona and the Purpose of the Second Spindle

Author(s) Robert L. Bunker

Reference *Journal of Book of Mormon Studies* 3/2 (1994): 1–11.

ISSN 1065-9366 (print), 2168-3158 (online)

Abstract The Liahona was given by the Lord as a communications device for Lehi to determine the appropriate direction of travel. This device contained two pointers, only one of which was necessary to provide directional information. But the Liahona was more than just a simple compass in function, for it additionally required faith for correct operation. Since a single pointer always "points" in some direction, the additional pointer was necessary to indicate whether or not the first pointer could be relied upon. This proposed purpose for the second pointer conforms to a well-established engineering principle used in modern fault-tolerant computer systems called "voting," in which two identical process states are compared and declared *correct* if they are the same, and *incorrect* if they are different. Hence the second pointer, when coincident with the first, would indicate proper operation, and when orthogonal, would indicate nonoperation.

The Design of the Liahona and the Purpose of the Second Spindle

Robert L. Bunker

Abstract: The Liahona was given by the Lord as a communications device for Lehi to determine the appropriate direction of travel. This device contained two pointers, only one of which was necessary to provide directional information. But the Liahona was more than just a simple compass in function, for it additionally required faith for correct operation. Since a single pointer always "points" in some direction, the additional pointer was necessary to indicate whether or not the first pointer could be relied upon. This proposed purpose for the second pointer conforms to a well-established engineering principle used in modern fault-tolerant computer systems called "voting," in which two identical process states are compared and declared *correct* if they are the same, and *incorrect* if they are different. Hence the second pointer, when coincident with the first, would indicate proper operation, and when orthogonal, would indicate nonoperation.

The Liahona was given by the Lord to Lehi for two basic purposes. First, it functioned as a communications device—pointing the direction of travel and providing written instructions from the Lord that were plainly visible to everyone in Lehi's party. Second, it functioned as a physical representation of the Lord's presence, just as the pillar of fire by night and cloud by day led the children of Israel as they traveled in the desert under the leadership of Moses (cf. Exodus 13:21). Similarly, the operation of the Liahona continually reminded Lehi and his family of the providence of the

Lord and who it was that was directing their journey. But here the parallel with the Israelites in the desert diverges. Unlike a cloud or pillar of fire, the Liahona is a physical object that provides a very specific function. It is also referred to as a *ball*, *compass*, or *director*, terms which provide a description of that function. As such, it stands as an especially unique object in all of human history—it is the only mechanical device, of which we have knowledge, ever constructed "by the hand of the Lord" for use by mortal man.[1]

> And I, Nephi, had also brought the records which were engraven upon the plates of brass; and also the ball, or compass, *which was prepared* for my father *by the hand of the Lord*, according to that which is written. (2 Nephi 5:12)
>
> And the ball or director, which led our fathers through the wilderness, *which was prepared by the hand of the Lord* that thereby they might be led . . . (Mosiah 1:16)
>
> And now, my son, I have somewhat to say concerning the thing which our fathers call a ball, or director—or our fathers called it Liahona, which is, being interpreted, a compass; *and the Lord prepared it.* (Alma 37:38)

To an engineer, the Lord is *the* consummate engineer. Consequently, any mechanical product of his hands would display the same perfection of functionality, economy of design, and great aesthetic beauty that is seen in his biological creations. Furthermore, with the Lord's knowledge of all things, the Liahona could very well utilize engineering principles completely unknown to Lehi and the great intellects of his time, or even Joseph Smith's time, but that have become well established in our time.

---

1 The origin of the Urim and Thummim(s) used by the ancient prophets and Joseph Smith has not been revealed, but they may also have been constructed by the Lord. They are distinguished from the Liahona, however, in that the latter device has moving components. Curiously, both instruments have a fundamentally common feature: both require faith for proper operation.

As confirmation of the expectation of exquisite workmanship and technical artistry, consider the words of Nephi: "And it came to pass that as my father arose in the morning, and went forth to the tent door, to his great astonishment he beheld upon the ground *a round ball of curious workmanship; and it was of fine brass*" (1 Nephi 16:10). Alma, who later possessed this sacred artifact, adds his perspective: "And behold, *there cannot any man work after the manner of so curious a workmanship*. And behold, it was prepared to show unto our fathers the course which they should travel in the wilderness" (Alma 37:39).

Nephi describes the internal construction as there being "within the ball . . . *two spindles* (1 Nephi 16:10).[2] Then the text goes on to specify the functionality of one of those spindles: "and *the one* pointed the way whither we should go into the wilderness" (1 Nephi 16:10).

What was the function of the other spindle? How were these spindles arranged? What was their range of motion? Why only two, not one, three, or more such spindles? Before these questions can be answered, it is important to identify one additional feature required of this device: "I, Nephi, beheld the pointers which were in the ball, that *they did work according to the faith and diligence and heed which we did give unto them*" (1 Nephi 16:28).

It is clear from this and other references that to the mortal observer (Nephi, Lehi, Laman, Lemuel, etc.), the Liahona not only provided directional information, but also indicated explicitly whether or not that information could be relied upon—whether faith was sufficient or not for the device to operate correctly. As

---

2 Nephi also refers to them as *pointers* (1 Nephi 16:28). The word *spindle* is suggestive of shape while *pointer* is descriptive of function. The *Oxford English Dictionary* (Oxford: Oxford University Press, 1970), s.v. "spindle," describes a "spindle" as an object used in spinning: "a slender rounded rod . . . tapering towards each end" (there are other definitions listed, but this seems to best fit the Book of Mormon context). Such a spindle-shaped pointer is often encountered in magnetic compasses (cf. n. 3) where some type of marking designates one end as north. The spindle in the Liahona used to designate direction would also have required differentiation between ends, either by color, texture, or shape. While use of the spindle shape is aesthetically pleasing and appropriately functional, there are sound engineering reasons for its selection: the symmetry inherently provides mechanical balance along its major and minor axes, a requirement for both compasses and the Liahona.

an example, after the family had been at sea for some period of time, Nephi's brothers became agitated and angrily bound him with cords: "And it came to pass that after they had bound me insomuch that I could not move, *the compass*,[3] which had been prepared of the Lord, *did cease to work*" (1 Nephi 18:12). And later, after the ship nearly founders in a severe storm, Nephi recalls: "And it came to pass after they had loosed me, behold, I took the compass, and *it did work whither I desired it*. And it came to pass that I prayed unto the Lord; and after I had prayed the winds did cease, and the storm did cease, and there was a great calm" (1 Nephi 18:21).

To complete the functional description of this special device, communication between the Lord and Lehi's party is further enhanced by written text on the outside of the ball: "And it came to pass that the voice of the Lord said unto him: *Look upon the ball, and behold the things which are written*" (1 Nephi 16:26); and by writing upon the spindles themselves: *"And there was also written upon [the pointers]*[4] *a new writing, which was plain to be read,* which did give us understanding concerning the ways of the Lord; and it[5] was written and changed from time to time, according to the faith and diligence which we gave unto it. And thus we see that by small means the Lord can bring about great things" (1 Nephi 16:29).

---

3 Since the magnetic compass in Lehi's time was still many centuries from discovery, the use of the word "compass" by Joseph Smith in translation to refer to the Liahona reinforces not only the analogy of directional function with the modern compass but also of design (cf. n. 2).

4 Antecedents of pronouns in the Book of Mormon are often ambiguous. Here "them" being plural is assumed to refer to the last plural descriptive noun—"pointers." However, the *Book of Mormon Student Manual: Religion 121 & 122* (Salt Lake City: The Church of Jesus Christ of Latter-day Saints, 1989), 16, under the heading "The Liahona," suggests that the antecedent of all the pronouns in this verse is the "writing" on the outside of the Liahona.

5 The most likely antecedent being referred to is the "writing" on the *outside* of the Liahona (cf. n. 4). The spindle would provide little area for writing, and any writing would be obscured by postulated designs. It seems unlikely that the Lord would attempt to use such space for regular communications, when a much larger area that was easier to read was available on the outside of the sphere. Other possible Liahona designs without the obscuring superstructure would make the visibility on the spindles better, but would not relieve the area constraint.

Though the sign-board, scratch-pad, or posting function is peripheral to the operation of the pointers, it provides insight into the size of the Liahona, which in turn determines the maximum size of the pointers. Consider that, if the Liahona were five inches in diameter (about the size of a cantaloupe melon or a coconut without its husk), there would be approximately 35 square inches of area available on the external surface for writing—about the size of a single book page (5 x 8 inches). The size of this area is proportional to the square of the diameter; the size increases linearly with the percentage of the spindle surface that we assume is usable. Diameters above six inches would make portability a problem (weight would scale a bit greater than the square of the diameter for reasons other than pure geometry), while a size smaller than about four inches would more severely limit the area available for written messages.

The amount of text inscribed on the pointers cannot be ascertained from Nephi's description, but the physical size of the writing must have been small; otherwise, the observation that it "was plain to be read" (1 Nephi 16:29) would have been unnecessary. Assuming the Liahona was about five inches in diameter, then the pointers were about the size of a finger in length and width, thus providing a modest area for text of a few square inches. An appropriate message to have inscribed on the pointers would have been the function of the second pointer in relation to the first and the necessity of faith for their proper operation. This would also be consistent with Nephi's statement that the message "did give us understanding concerning the ways of the Lord" (1 Nephi 16:29). And what are the "ways of the Lord"? The unity of direction and purpose when the pointers were functioning in response to obedience and faith could represent a powerful symbolic message. It is difficult to see how such phrasing would apply to the messages inscribed on the outside of the Liahona (cf. n. 5). However, unanimity of opinion on these finer points is not necessary to support the premise of this paper, so further justification will not be attempted.

Having established the functional requirements as specified above, the postulated design of the Liahona differs little in its external form from artist Arnold Friberg's famous depiction[6] of that discovery moment where Lehi is holding the newly found Liahona in his hands while his family looks on with astonishment. This artistic depiction of the Liahona as a spherical shape is consistent with the "ball"-like description. Curiously, there is no engineering requirement driving the design to a sphere—a short cylinder would have been sufficient—so its shape must have had additional symbolic meaning. Perhaps it represented the earth, more than half of whose circumference Lehi and his family would be traversing.

At the top there would be an opening or openings to view the spindles inside the sphere. The eight triangular holes depicted by Friberg are simply speculation. From an engineer's viewpoint, a prime number of openings (three, five, seven, etc.) would provide less obscuration of the pointers, but the asymmetry might detract from the aesthetics. Additionally, there are several other conceivable designs that could provide the necessary functionality while maintaining the spherical appearance, but further discussion of these is beyond the scope of and not relevant to the premise of this paper. (Figure 3 illustrates a few of an engineer's speculative "improvements" of an artist's speculative depiction. Nevertheless, Friberg, or whoever provided the inspiration for the Liahona's construction, did an excellent job of thinking through many necessary construction details not described in the scriptural text.)

Now to return to that most important design issue—the purpose of the second pointer. As mentioned in Nephi's description above, one pointer necessarily provided directional information. But to appreciate the elegance of the Liahona's design, from an engineer's viewpoint, is to understand the function of the *second* pointer. Since a single pointer is always pointing a direction, it was likely the role of the second pointer to provide the necessary additional information about whether the Liahona was "operational," meaning that the pointing information from the first pointer was reliable.

There is but one engineering approach that provides the necessary functionality and meets all of the above requirements both efficiently and simply. This is how it would have worked: if an

6 Arnold Friberg, "The Liahona," Gospel Art, #302.

observer viewed the pointers and saw only a single pointer, as seen in figure 1, then they were both aligned in the same direction, one on top of the other, and the director was providing correct information. Lehi's party could then follow the indicated direction with confidence that it was the Lord's instruction. If, on the other hand, the two pointers were cross-ways to each other—forming an "x" as shown in figure 2—then the device was not functioning, and the pointing information was not reliable. No other information was required of the Liahona, so no more than two pointers were needed. But the requirements demand a minimum of two.

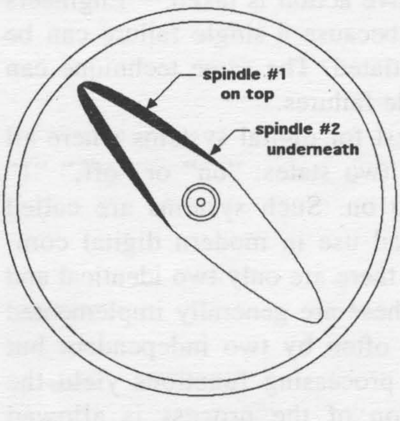

Figure 1. "proceed as indicated"

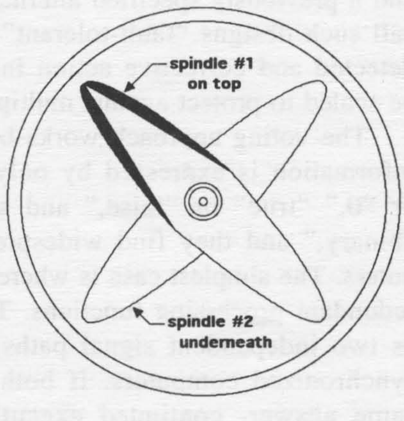

Figure 2. "not in service"

While this may seem a trivial solution, it nevertheless employs a basic fundamental principle of engineering called "voting of redundant strings," first developed about fifty years ago to make the digital computers of that era more reliable.[7] Today it is used on advanced "fly-by-wire" digital aircraft control systems,

---

7 Algirdas Avižienis et al., "Fault-Tolerant Computing: An Overview," *IEEE Computer* 4/1 (January-February 1971): 10.

nuclear reactor controls, railroad switching,[8] telephone switching,[9] NASA's Space Shuttle,[10] sophisticated interplanetary and earth-orbiting spacecraft,[11] and any application where exceptionally high reliability is a requirement to prevent loss of life or valuable property. To assure such reliability, engineers use this voting technique to determine if two (or more) identical systems, executing the exact same processes at precisely the same time, each have the correct answer. If the result of the vote is the same for each independent string, correct execution is assumed to have occurred, and the system proceeds to implement the expected function. However, if a failure occurs in one of the strings, then the votes will be different. When this happens a fault or error is declared, and a previously specified alternative action is taken.[12] Engineers call such designs "fault-tolerant" because a single failure can be detected and corrective action initiated. The same technique can be scaled to protect against multiple failures.

The voting approach works best for digital systems where all information is expressed by only two states: "on" or "off," "1" or "0," "true" or "false," and so on. Such systems are called "binary," and they find widespread use in modern digital computers. The simplest case is where there are only two identical and redundant processing functions. These are generally implemented as two independent signal paths, often by two independent but synchronized computers. If both processing functions yield the same answer, continued execution of the process is allowed because no failure has occurred. If, on the other hand, the voting

8 Algirdas Avizienis, "Software Fault Tolerance," XI World Computer Congress (IFIP Congress, 1989), San Francisco, CA, 28 August–1 September, 1989 (advanced version), 23–24.

9 John P. Hayes, *Computer Architecture and Organization* (New York: McGraw-Hill, 1988), 664.

10 J. R. Sklaroff, "Redundancy Management Technique for Space Shuttle Computers," *IBM Journal of Research and Development* 20 (January 1976): 20.

11 Hayes, *Computer Architecture and Organization*, 664. Also compare proposed future space applications using this technique: Blair F. Lewis and Robert L. Bunker, "MAX: An Advanced Parallel Computer for Space Applications," *Proceedings of the AIAA/NASA Second International Symposium on Space Information Systems*, Pasadena, CA, 17–19 September 1990, 773. Some applications are still classified.

12 Avizienis et al., "Fault-Tolerant Computing: An Overview," 5–8.

yields different answers, then the process is aborted and a failure is declared. Note that there is no *a priori* way of determining which of the two process streams failed without additional information, only that a failure has occurred on one of the two channels.

While a simultaneous failure in both strings is possible, it is excluded from consideration because the single string failure rate is assumed to be sufficiently low that the probability of two failures is statistically "insignificant" within the time it takes to detect a fault by voting. Good engineering practice requires that this case be checked to assure that the time between votes is sufficiently short to meet the "insignificance" criteria.

Two-way voting is often used in functions where time does not play a critical role and where it is possible to stop and implement some test process (either automatically or through human intervention) to determine which path failed. It is the *minimum* required to achieve fault or failure indication. It also minimizes the amount of hardware or equipment necessary to implement the fault strategy. In modern systems it requires duplicate hardware; for the Liahona it required a duplicate spindle. And two-way voting was all that the Liahona required to provide the specified function; hence, only two spindles were necessary. See figure 3 for a three-dimensional drawing of how it might have looked with the obscuring ball cut away.

For those interested in this fault-tolerant design approach, three-way voting provides an instantaneous indication of which channel failed because two of the three paths still yield a common result and the assurance of correct execution. Such indicators are used in the latest aircraft control systems where a few lost microseconds could mean the destruction of the aircraft. To achieve an even greater tolerance to failure, superreliable systems implement higher-order voting schemes. NASA's Space Shuttle, for example, uses four identical computers, executing in lock-step and voting all results to assure failure-free performance even after two failures.[13]

---

13 Voting strategies will only protect against hardware faults since the same software is executed in all four computers. To protect against a software failure, the Shuttle has a fifth computer of a completely different design, made by a different company, running software written by different people, that can provide the same functionality. Thus even greater fault tolerance is achieved.

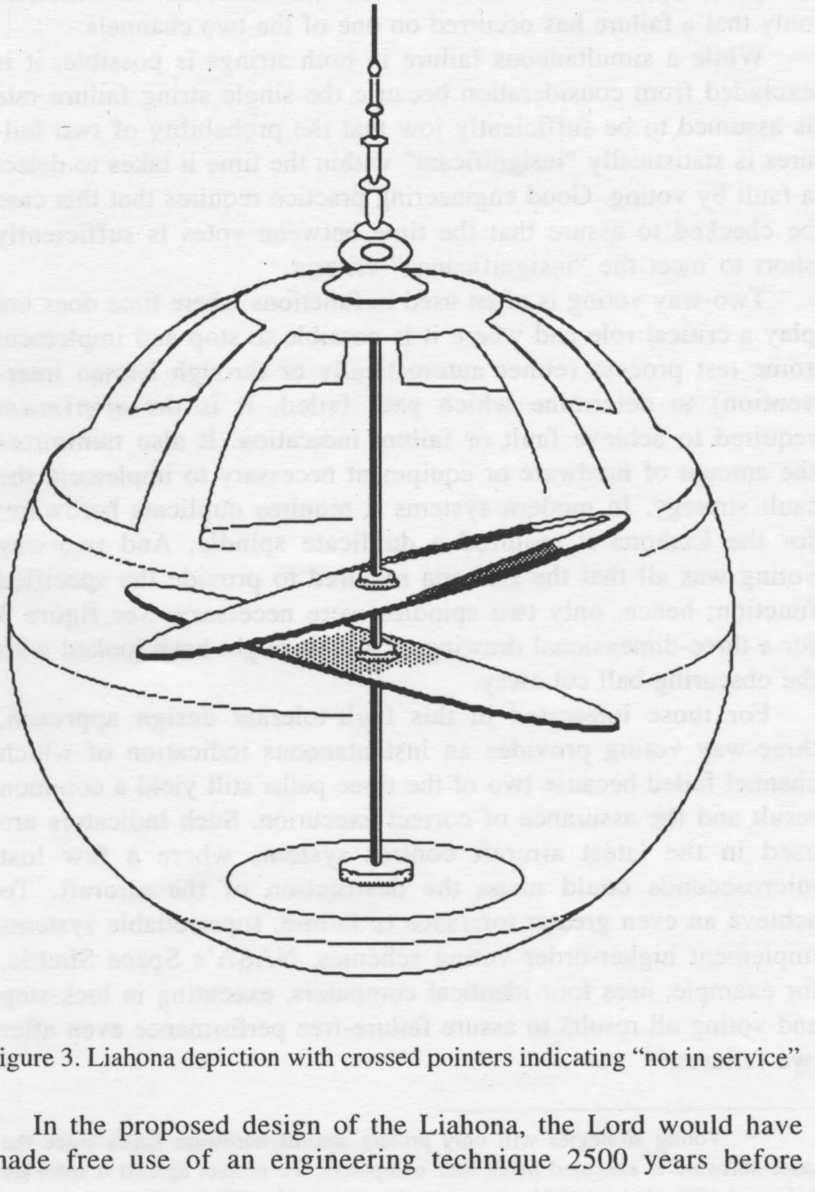

Figure 3. Liahona depiction with crossed pointers indicating "not in service"

In the proposed design of the Liahona, the Lord would have made free use of an engineering technique 2500 years before man invented it in the 1940s[14] as a way to build reliable digital systems.[15] The implementation is simple, elegant, and in every way satisfies the requirements without any superfluous function or unnecessary complexity. As a potential confirmation, examine carefully this passage in Alma:

> And [the Liahona] did work for them according to their faith in God; therefore, if they had faith to believe that God could cause that those spindles should point the way they should go, behold, it was done; therefore they had this miracle, and also many other miracles wrought by the power of God, day by day. (Alma 37:40)

Here the word *spindles* is used in the plural—suggesting that it requires both spindles to "point the way" to go. And that is exactly what both spindles are doing in the proposed design when they are "pointing the way."

---

14 Avizienis et al., "Fault-Tolerant Computing: An Overview," 10. See also Algirdas Avizienis, H. Kopetz, and J.-C. Laprie, eds., *The Evolution of Fault-Tolerant Computing* (New York: Springer, 1987).

15 Those knowledgeable about such systems may claim the Liahona is an analog instrument (having an arbitrarily large number of output states) and would be correct about the directional information provided. But the additional information about whether the indicated direction is "true" or "false" is a digital function that requires only an expression of two states.