

The following paper was prepared by Karen R. Burns, PhD (TIGHAR # 2071); Richard L. Jantz, PhD; Thomas F. King, PhD (TIGHAR #0391CE); and Richard E. Gillespie, Executive Director of TIGHAR, for release at the annual convention of the American Anthropological Association in Philadelphia on December 5, 1998.

Amelia Earhart's Bones and Shoes?

Current Anthropological Perspectives on an Historical Mystery

Karen Ramey Burns¹, Richard L. Jantz², Thomas F. King³, and Richard E. Gillespie⁴

Introduction

The disappearance of aviation pioneer Amelia Earhart in 1937 is a mystery that continues to grip the imagination of many. Although the most widely held assumption is that she simply crashed and sank in the Pacific Ocean, many speculative and not-so speculative alternative explanations have been advanced over the years. An ongoing interdisciplinary study by The International Group for Historic Aircraft Recovery (TIGHAR) has recently generated anthropological data consistent with the proposition that Earhart and her navigator, Fred Noonan, landed and later died on Nikumaroro Island in the Republic of Kiribati.

TIGHAR is a non-profit research, educational, and historic preservation organization based in Wilmington, Delaware, one of whose specialties is the investigation of aviation-related historical puzzles like the disappearance of Earhart. Following up on a reconstruction of Noonan's most likely navigational decisions given the practices

of the time, TIGHAR's Earhart research has focused on Nikumaroro, an uninhabited island some 400 miles southeast of Howland Island, Earhart's destination at the time of her loss. Four archeological surveys and test excavations have been conducted to date on the island with the cooperation of the Kiribati Government, and extensive archival and oral historical research is ongoing. Background documentation and current research findings can be accessed through TIGHAR's web site at www.tighar.org.

Nikumaroro, then known as Gardner Island, was uninhabited in 1937, and is so today. In 1938, however, it became an important part of the Phoenix Island Settlement Scheme (cf. Maude 1968; Laxton 1951) of the British Western Pacific High Commission, and was occupied by I-Kiribati colonists until 1963 when the effort was given up. In 1944–45 the island also hosted a U.S. Coast Guard Loran station.

In 1960, the late Floyd Kilts, a retired



Floyd Kilts

The Floyd Kilts Story

Coast Guardsman, gave an interview to the San Diego, California *Tribune*, in which he posited Earhart's crash-landing on Nikumaroro (Skarr 1960). His speculation was based on what he said he had been told by one of the colonists while Kilts was helping dismantle the Loran station in 1946.

A native tried to tell me about it... It seems that in ... 1938 there were 23 island people, all men, and an Irish magistrate planting coconut trees... They were about through

and the native was walking along one end of the island. There in the bush about five feet from the shoreline he saw a skeleton.

What attracted him to it was the shoes. Women's shoes, American kind... size nine narrow...

The magistrate was a young Irishman, who...thought of Amelia Earhart right away. He put the bones in a gunnysack and...in a 22-foot, four oared boat started for Suva, Fiji...

When only about 24 hours out of Suva, he died. The natives are superstitious as the devil and the next night ... they threw the gunnysack full of bones overboard.

Kilts' story, though laden with fantastic premises like the sailing of a small four-oared boat from Nikumaroro to Fiji, contains certain elements that resemble



Gerald Gallagher's grave on Nikumaroro. TIGHAR photo by J. Clauss.

known facts. There was never an "Irish magistrate" on the island, but there was a British colonial administrator of Irish descent, Gerald B. Gallagher, whose nickname was in fact "Irish."

Gallagher did not die in a boat 24 hours out of Fiji, but he did die on Nikumaroro about 24 hours after returning from leave in Fiji. What sort of actual course of events the story might reflect, if any, has until recently been a matter of mere speculation.

The Nikumaroro Shoe

In 1991, while conducting test excavations at a site on Nikumaroro suspected to have Earhart associations, TIGHAR encountered a surface scatter of shoe fragments. These included a Cats-Paw replacement heel, pieces comprising most of a rubber sole, and a brass shoelace eyelet. Experts from the Cat's Paw Division of the Biltrite Corporation identified the heel as dating from the mid-1930s and the sole, which exactly aligns with the nail holes in the heel, as probably coming from a woman's blucher oxford of



The heel, sole, and eyelet found on Nikumaroro. TIGHAR photos by P. Thrasher

the same era. Reassembly of the fragmented sole indicates an overall length equivalent to about a size nine. Photographs of Earhart taken shortly before her disappearance show her wearing blucher oxford style shoes of



Detail of Amelia Earhart standing on the wing of her airplane ten days before she disappeared. The shoe is a blucher oxford with brass eyelets, approx. size 8 1/2 or 9. The lighter shade of the lower heel suggests that it may be a replacement heel.

that approximate size with brass shoelace eyelets and what appear to be recently replaced heels (TIGHAR 1996: 25). This discovery, of course, gave added credence to the Kilts account, and justified further detailed investigation of the site in 1997. Analysis of the results of the 1997 work is continuing.

The Tarawa Papers

In the summer of 1997, historical researcher and TIGHAR member Peter McQuarrie discovered a file of papers in the national archives of the Republic of Kiribati on Tarawa Atoll pertaining to the discovery of bones on Nikumaroro (c.f. TIGHAR 1997). The file contained copies of wireless traffic between Gallagher on Nikumaroro and various officials on Ocean Island, on Tarawa, and in Fiji.

In the first message, dated September 23, 1940, Gallagher reports the discovery of a skull "which is just possibly that of Amelia Earhart." In a second message dated the same day, Gallagher reports that the skull had been discovered "some months ago" and

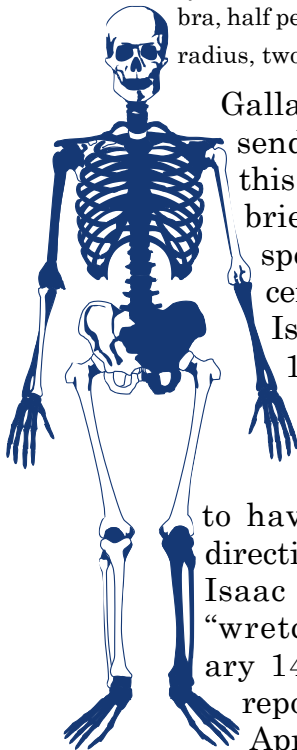
buried. He goes on to say that:

Thorough search has now produced more bones (including lower jaw) part of a shoe a bottle and a sextant box. It would appear that:

- (a) Skeleton is possibly that of a woman,
- (b) Shoe was a womans and probably size 10,
- (c) Sextant box has two numbers on it... 3500 (stencilled) and 1542— sextant being old fashioned and probably painted over with black enamel.

Gallagher was directed by the Western Pacific High Commission to keep the matter “strictly secret,” and was asked for more information. On October 6, 1940 he describes the shoe as “a stoutish walking shoe or heavy sandal” and on October 17 he reports that the discovery site included the “remains of fire, turtle, and dead birds.” He also reports that the bones recovered comprise:

... only skull, lower jaw, one thoracic vertebra, half pelvis, part scapula, humerus, radius, two femurs, tibia and fibula.



Unshaded bones are the ones found on Niku.

Gallagher was instructed to send the bones to Fiji, and this he did, though they were briefly intercepted and inspected by the medical officer on Tarawa, Dr. Lindsay Isaac, who on February 11, 1941 pronounced them the remains of an elderly Polynesian male. After receiving what seems to have been rather pointed direction to send the bones on, Isaac reported releasing the “wretched relics” on February 14, and the Commission reported receiving them on April 28th, 1941.

The Hoodless Analysis

Research in the Western Pacific High Commission’s archives in London has recently produced evidence of the next step in the bones’ journey. A report by the late Dr. D.W. Hoodless of the Central Medical School in Suva, Fiji (discussed below) docu-

ments his analysis of the remains, and his conclusion that they “definitely” represented a male but that they were probably not those of a Polynesian, or Micronesian. Instead, he thought them most likely the bones of a “short, stocky European, or even a half-caste” (TIGHAR 1998:9). Importantly, the report includes Dr. Hoodless’ hand-written notes with the measurements and first-hand observations he made on the bones. These are reproduced in facsimile on page 7.

Re-analysis of Hoodless’ Observations

The Hoodless report and his handwritten notes were examined by forensic skeletal biologists Burns and Jantz independent of one another, and each separately analyzed Hoodless’ measurements. Two questions were considered:

- (1) To what extent can the opinions offered by Hoodless about the character of the bones be relied upon?
- (2) What can be said about the bones based on the application of modern analytic procedures to Hoodless’ measurements?

Reliability of the Observations

Hoodless’ report begins:

I have to-day examined a collection of bones forming a part of a human skeleton. These bones were delivered to me in a wooden box by Mr P.D. Macdonald of the Western Pacific High Commission.

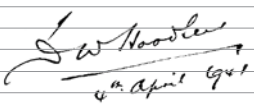
He goes on to list the thirteen bones included, commenting that among them were:

... a skull with the right zygoma and malar bones broken off ...

The zygoma and the malar are the same bone. This raises some question about the extent of Hoodless’ skeletal knowledge.

Hoodless notes that:

[f]rom this list it is seen that less than half of the total skeleton is available for examination.

1	Orbital width	38.5 mm
2	Orbital height	33.5 mm
$\text{orbital index} = \frac{oh \times 100}{ow} = \frac{33.5 \times 100}{38.5} = 87.0$		
<p><i>This indicates a European - (Polynesians are about 89.0)</i></p>		
Skull		
3	Length	182 mm
4	Breadth	137 mm
$\text{cephalic index} = \frac{B \times 100}{L} = \frac{137 \times 100}{182} = 75.3$		
<p><i>This indicates also a European.</i></p>		
Karl Pearson's formula for stature		
⑤	$S = 70641 + 2894 \times H$ Humerus = 324	$\therefore \text{height is } 163406 \text{ cm}$ $= 5 \text{ ft } 4.3 \text{ in}$
⑥	$S = 78664 + 2376 \times T$ Tibia = 372	$\therefore \text{height is } 167051 \text{ cm}$ $= 5 \text{ ft } 5.7 \text{ in}$
⑦	$S = 89925 + 3271 \times R$ Radius = 24.5	$\therefore \text{height is } 170064$ $= 5 \text{ ft } 6.5 \text{ in}$
<p>Average of these three measurements is <u>5 ft 5.5 inches</u></p>		
 <i>J. W. Hoodless</i> <i>4th April 1941</i>		

As noted, only thirteen bones are listed in this inventory. Officially, the adult human skeleton is composed of 206 bones, or over 130 bones if bones fused in adulthood (e.g. the cranium) are counted as single units and the teeth and very small bones are left out. In any event, thirteen bones is less than 10 percent of the bones of the skeleton. Hoodless examined *much less* than “less than half” of the skeleton.

He goes on to observe that:

[t]hese bones are very weather beaten and have been exposed to the open air for a considerable time. Except in one or two small areas, all traces of muscular attachments and the various ridges and prominences have been obliterated.

Note that he says that “except in one or two small areas, all traces of muscular attachments.... have been obliterated.” This observation is important in evaluating a subsequent statement.

Hoodless continues...

By taking measurements of the length of the femur, tibia and the humerus, I estimate that those bones belonged to a skeleton of total height of 5 feet 5.5 inches approximately.

When speaking of stature, a value of a half inch is *not* “approximate.” The range that includes the standard error of estimate in long bones is between 3 and 4 inches. About one third of the population is not even covered by this range.

Hoodless then concludes that:

[f]rom the half sub-pubic angle of the right innominate bone, the “set” of the two femora, and the ratio of the circumferences of the long bones to their individual lengths, it may be definitely stated that the skeleton is that of a MALE. *[emphasis in original]*

To a skeletal biologist, these read like the words of a person who never expects to be challenged. Forensic anthropologists will recognize this kind of statement as common in the analysis of skeletal remains by non-osteologists. The victim is not going to contradict the opinion, and the people reading the report are concerned only with the bottom line, not the methodology. Snap judgements are made to satisfy those requesting the report, based on analysis that lacks methodological rigor. In fact, of course, human variation is such that population norms must be taken into account when assessing sex from skeletal remains. Even if the population is well-known to the observer, caution is important. The overlap between the normal curve for male measurements and the normal curve for female measurements is considerable.

Hoodless does not provide a number of key pieces of data. What is the actual measurement of the sub-pubic angle? What is the femoral head measurement? What population database is he using? Is the database appropriate for the unknown individual in question? What about the angle of the sciatic notch, the size of the mastoid processes, the rugosity of the occipital, the shape and size of the brow ridge, the contour of the frontal bone, and other sex indicators?

He proceeds to discuss the individual's age:

Owing to the weather beaten condition of all the bones, it is impossible to be dogmatic in regard to the age of the person at the time of death, but I am of the opinion that he was not less than 45 years of age and that probably he was older: say between 45 and 55 years.

Hoodless does not mention cranial sutures, pubic symphysis contour, rib ends, dental wear, osteoarthritis, or any other skeletal age indicator. What is the basis for his opinion? Of course, much of the research on skeletal age has been published since the time of Hoodless's report, but a ten year interval in the middle or late years of life is a narrow range, and he must have had *some* basis for his conclusion. If the skeletal material is in as poor condition as he says, there is no way to determine age within such a narrow range even today except by using microstructural analysis.

Finally, Hoodless comments that:

I am not prepared to give an opinion on the race or nationality of this skeleton, except to state that it is probably not that of a pure South Sea Islander – Micronesian or Polynesian. It could be that of a short, stocky, muscular European, or even a half-caste, or a person of mixed European descent.

In other words, Hoodless says he is not prepared to give an opinion, but then he gives a rather precise opinion, without providing a basis for it. In assessing the reliability of this opinion, one must consider that:

- “Short” is a relative term. Assessing stature requires an accurate assessment of the long bones.
- “Stocky” requires some idea of weight. Without a belt or measurable clothing, weight cannot be determined from skeletal remains.
- “Muscular” requires analysis of muscle attachment areas, which Hoodless previously described as “obliterated” except

in “one or two small areas.”

- “Race” is very difficult to determine, and racial mixture is even more difficult, yet Hoodless suggests “half-caste” with no stated basis for his opinion.

Hoodless concludes his report by suggesting that:

[i]f further details are necessary I am prepared to take detailed and exact measurements of the principal bones in this collection, and to work out the various indices (e.g. the platymeric index for the femur or the enemic index for the tibia) but if such a detailed report is required the obvious course to adopt would be to submit these bones to the Anthropological Dept of the Sydney University where Professor Elkin would be only too pleased to make a further report.

This one paragraph suggests that Hoodless knew he might have missed something in his analysis. Unfortunately, there is no evidence to indicate that his very reasonable suggestion that the bones be subjected to independent analysis was taken up; the University of Sydney has reported no record of having received the bones.

In summary, there is little reason to trust Dr. Hoodless' conclusions about the age, sex, or racial background of the individual represented by the Nikumaroro bones.

Reanalysis of the Measurements

Skeletal measurements taken over 55 years ago by a now-deceased individual of unknown expertise, with no description of the methods or assumptions employed, must be used with great caution. In the case of the Nikumaroro bones, although Hoodless says that six long bones were present, he presented information on only three. For the cranium, he supplied only four measurements. We have no way of judging the reliability of the data he does present. The measurements he provides do not appear unreasonable, however, and in any event they are all we have to work with until the bones themselves are recovered.

Both Burns' and Jantz' analyses were

based on the assumption that Hoodless measured orbit breadth and tibia length in the same way as these variables are recorded in current data bases. This may not be correct, but we have no basis for assuming that he measured them in any different way.

Burns and Jantz both employed FORDISC 2.0 in their reanalyses of Hoodless' cranial measurements. FORDISC is an interactive computer program for the classification of unknown adult crania according to race and sex, using any combination of standard cranial measurements (c.f. Moore-Jansen, Ousley, and Jantz 1994; Ousley and Jantz 1996). Both arrived at the following conclusions:

Ancestry: The skull is more likely European than Polynesian, although it cannot be excluded from any population. Comparing the skull measurements to European, Polynesian and Micronesian populations, it is most similar to Norse females (see Figure 1).



Sex: Assuming the skull represents a person of European ancestry, the FORDISC analysis indicates that the individual represented was most likely female. Unfortunately the level of certainty is very low; the female/male probability is ca. .65/.35. If Hoodless measured orbit breadth in a different way,

such that the orbits were in fact a couple of millimeters greater as measured today, this would change the classification to male, with male/female probabilities of .53/.47

Stature: Jantz gave the question of stature special attention. Noting that Hoodless got rather widely varying estimates, depending upon which bone he used, Jantz employed formulae derived from a modern reference sample (Ousley

1995) in the forensic anthropology data bank at the University of Tennessee, Knoxville and obtained the following:

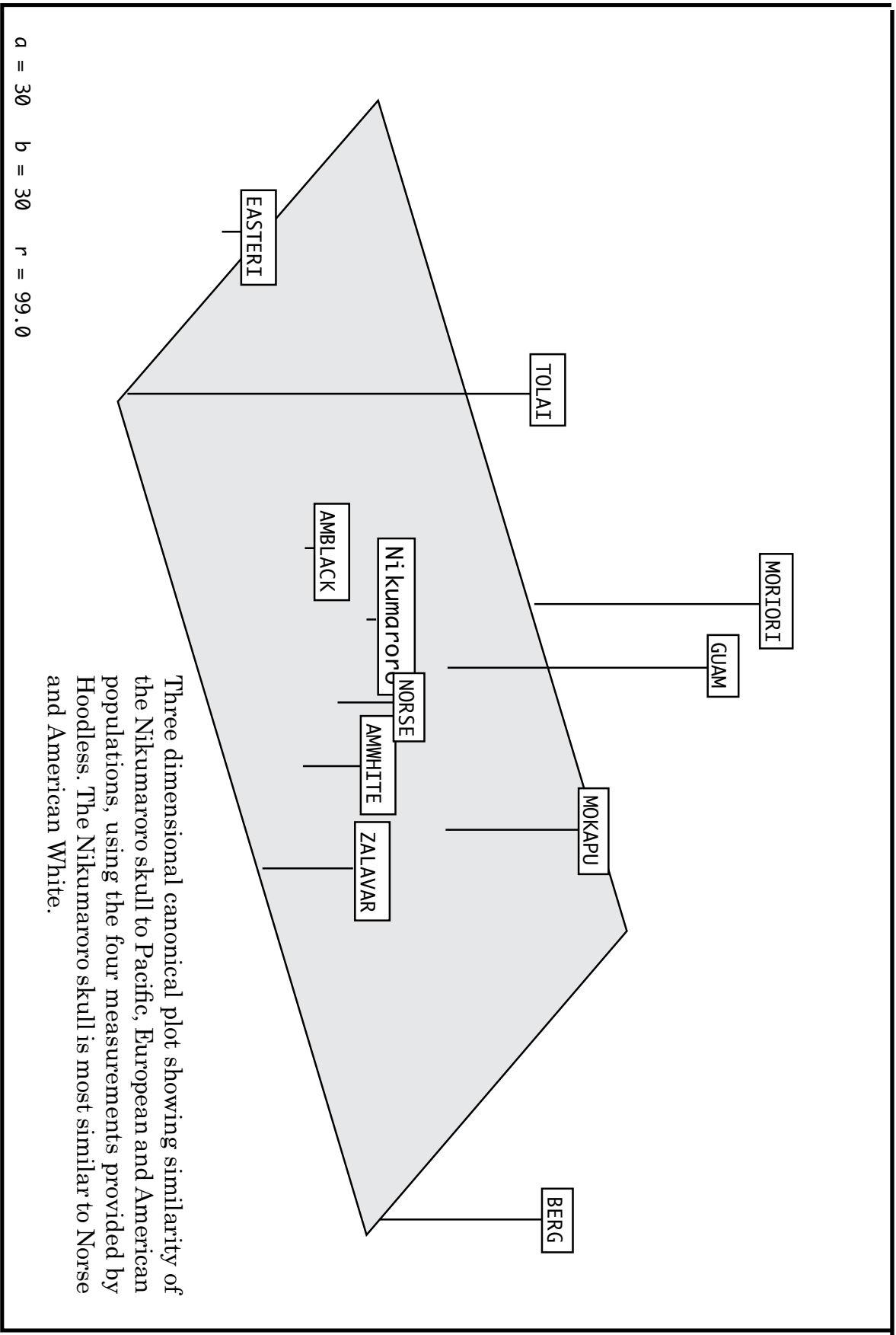
Bone/length	Stature of individual assuming	
	Female	Male
Humerus @ 32.4 cm:	169.2 cm./66.6"	173.0 cm./68.1"
Tibia @ 37.2 cm:	167.9 cm./66.1"	172.7 cm./68.0"
Radius @ 24.5 cm:	171.7 cm./67.6"	173.7 cm./68.4"

These estimates have confidence intervals that range from ca. 162.6 cm./64" to 177.8 cm./70". Estimates based on the different bones do not vary greatly from one another—certainly not to the extent Dr. Hoodless' did. If the bones are those of a female, the best estimate is ca. 5'6" to 5'7", if male about 1.5 inches more. Since the results from the tibia fall into line with those derived from the other measurements, it is likely that Hoodless measured the tibia comparably with the way Jantz measured the tibiae in the reference sample.

Turning the question around, Jantz asked what bone lengths would be expected from a women of Earhart's height? According to TIGHAR records, Earhart gave her height as 5'8", but there is some indication she may have been closer to 5'7". Regression predictions of bone length from stature for women of 5'8" and 5'7" are as follows:

	5'8"(172.72cm)	5'7"(170.18cm)
Humerus		
Observed length	324 cm.	324 cm.
Predicted length	322.4 +/-10.95	318.4 +/-10.95
Observed-Predicted	1.6	5.6
Radius		
Observed length	245	245
Predicted length	238.0 +/-9.67	236.7 +/-9.67
Observed-predicted	6.0	8.0
Tibia		
Observed length	372	372
Predicted length	377.9 +/-14.25	373.4 +/-14.25
Observed-predicted	-5.9	-1.4

These results indicate that the Nikumaroro bones fit Amelia Earhart's stature very well. The observed lengths all fall within one standard deviation of the estimates. For the humerus and tibia, the departures are trivial.



Three dimensional canonical plot showing similarity of the Nikumaroro skull to Pacific, European and American populations, using the four measurements provided by Hoodless. The Nikumaroro skull is most similar to Norse and American White.

Figure 1

Based on the information now in hand, Jantz and Burns both concluded that the remains found on Nikumaroro in 1939-40 represented an individual who was:

- (1) More likely female than male
- (2) More likely white than Polynesian or other Pacific Islander
- (3) Most likely between 5'5" and 5'9" in height

Conclusions

It is, of course, impossible to know whether the bones inspected by Dr. Hoodless in 1941 were in fact those of a white female, and if anything even less possible to be sure that they were those of Amelia Earhart. Only the rediscovery of the bones themselves, or the recovery of more bones from the same skeleton on the island, can bring certainty. What we can be certain of is that bones were found on the island in 1939-40, associated with what were observed to be women's shoes and a navigator's sextant box, and that the morphology of the recovered bones, insofar as we can tell by applying contemporary forensic methods to measurements taken at the time, appears consistent with a female of Earhart's height and ethnic origin. Historical, ethnohistorical, archeological, and forensic research is continuing in an effort to achieve more definitive conclusions. Current planned research includes further inspection of archives in Tarawa and in England, further study of the site where the shoe parts were found in 1991, and a detailed archeological survey of another site on Nikumaroro that closely matches Gallagher's description of the



bones discovery site. Details of the ongoing investigation may be accessed via www.tighar.org.

References Cited

- Laxton, P.B.
1951 "Nikumaroro" *Journal of the Polynesian Society* 60:134-60, Honolulu.
- Maude, H.E.
1968 "The Colonization of the Phoenix Islands." In *Of Islands and Men: Studies in Pacific History*, H.E. Maude, editor, pp. 315-42, Oxford University Press, Melbourne.
- Moore-Jansen, P.H., S.D. Ousley, and R.L. Jantz
1994 *Data Collection Procedures for Forensic Skeletal Material*. Third Edition. Report of Investigations No. 48, Department of Anthropology, The University of Tennessee, Knoxville.
- Ousley, S. D.
1995 Should we estimate biological or forensic stature? *Journal of Forensic Sciences* 40:768-773.
- Ousley, S. D. and R. L. Jantz
1996 *Fordisc 2.0: Personal Computer Forensic Discriminant Functions*. The University of Tennessee, Knoxville.
- Skarr, Lew
1960 "San Diegan Bares Clue to Earhart Fate." *San Diego Tribune*: July 21, 1960.
- TIGHAR (The International Group for Historic Aircraft Recovery)
1996 "Found Objects." *TIGHAR Tracks: Journal of The International Group for Historic Aircraft Recovery*: 12:2/3:11-27, TIGHAR, Wilmington.
1997 "The Tarawa File." *TIGHAR Tracks: Journal of The International Group for Historic Aircraft Recovery*: 13:1:18-31, TIGHAR, Wilmington.
1998 "The Noonan Project." *TIGHAR Tracks: Journal of The International Group for Historic Aircraft Recovery*: 14:1:9-11, TIGHAR, Wilmington.
- ¹ Department of Sociology, Anthropology, and Social Work, University of North Carolina at Charlotte
- ² Department of Anthropology, University of Tennessee at Knoxville
- ³ Consultant in Archeology and Historic Preservation, Washington DC
- ⁴ Executive Director, The International Group for Historic Aircraft Recovery (TIGHAR)

