Two words of the same length are said to crash with each other if they contain the same letter in the same position; thus, TORUS and SNOTUT crash because both have the letter U in the fourth position, but GUFAW and MAIDEN do not. FIGHT and MIGHT crash in several positions simultaneously.

Consider a list of words, all of the same length, such as might be obtained from a dictionary. What is the smallest set of words that can be taken from this list with the property that every word in the list crashes with at least one word in the set? To echo the title of this article, what is the smallest pan-crashing word set? For example, if the word list is "ARE FOR THE HIS HER CAN ONE EAR WAS AND", a pan-crashing word set is "WAS ARE HER: FOR crashes with HER, THE with ARE, HIS with HER, CAN with WAS, ONE with ARE, EAR with WAS (or HER), and AND with ARE.

In general, such a word set is not unique; there are many different ones that will do the job. In fact, there are likely to be many sets that collectively have no words in common.

Two general questions have motivated this study: (1) how does the size of the smallest pan-crashing word set vary with the length of the word? (2) how does the size of the smallest pan-crashing word set vary with the size of the original list? The second question is somewhat harder to investigate than the first, because large word lists are hard to compile and unwieldy to check for crashes, unless a digital computer is available.

More generally, one can abandon the requirement that the words in the pan-crashing set come from the words of the list. Instead, one can ask for the best set of letters in each position which collectively crash all the words on the list -- in the earlier example, (AH) in the first position, (A) in the second, and (ER) in the third. To avoid the trivial solution of (AB...Z) in one position, we require that two or more positions be represented with letters. Once this is satisfied, that letter set having the fewest total letters is judged the best.

For our word list, we have taken the Merriam-Webster Pocket Dictionary, allowing any word (other than those labeled as abbreviations) which appears there in boldface type; thus, common plurals, past tenses and gerunds not separately specified are excluded. From this dictionary, we have taken lists of three through eight letters, ranging from seven to seven.

The three-letter word set has been interesting one of the many word sets considered by this study. For example, the smallest pan-crashing word set, one considers

- all ear good
- all eye IOs

As the length of a word set increases, the number of possible letters increases, and the number of different words in a word list increases exponentially. In the case of three-letter word sets, there are a total of 26^3 = 17,576 possible words. The smallest pan-crashing word set contains seven words.

A few words in the list are quite common, and the best strategy is to try to avoid them. It turned out that having at least two more words in the word list is quite important; for example, the words areaway, briebrary are fairly common.

It turned out that a good strategy is to use vowels in as many positions as possible. For example, the six-letter word set /a e i o u/ is a pan-crashing word set. It contains 26^6 = 30,891,577 possible words. The smallest pan-crashing word set contains 23 words.

Having considered word sets of three through eight letters, the smallest pan-crashing word sets are:

- three-letter word set: 7 words
- four-letter word set: 15 words
- five-letter word set: 23 words
- six-letter word set: 41 words
- seven-letter word set: 69 words
- eight-letter word set: 107 words
The three-letter pan-crashing word set is perhaps the most interesting one of all, for its length depends upon which edition of the Pocket Dictionary is used. The 1964 edition lists TNT and DDT as nouns (not abbreviations), despite the fact that they are capitalized and are pronounced by spelling out the letters; the 1974 edition adds at least two more, VIP and IOU. It is unfortunate that the size of the minimum pan-crashing word set apparently depends upon whether or not one considers IOU to be a word:

all ear goo ire nth out pen sly (1964 edition)
all eye IOU nay out pro sea (1974 edition)

As the length of words taken from a given dictionary increases, the size of the minimum pan-crashing word set slowly decreases. For three-letter words, the minimum pan-crashing set is on the line between seven and eight words. Pan-crashing sets of size seven can be fairly easily found for words of length four, five and six, and sets of size six, for words of length seven and eight:

aeon does fiat maule once puny trio
chore lemon mousy naiaid plous quall sleet
adieu beanie cocoons laurel queasy ritual Taosism
areaway Bedouin gaseous satiate thereon unquiet
breviary employee Ghanaian gorgeous playsuit sturgeon

A few words about methodology may be in order here. As the word-length became larger (five or more), trial and error revealed that the best strategy for constructing a pan-crashing word set was to make sure that E and Y appeared in the final letter position, and that the vowels A, E, I, O and U all appeared in the three preceding positions. It turned out that the number of words in the dictionary list not containing at least one of these letters in the appropriate position was quite small; for example, the eight-letter exceptions were amethyst, babushka, catalyst, draughts, paroxysm, penumbra, strength and triptych. These could be readily accommodated by picking matching letters in the early part of a pan-crashing word, or at the end of one.

It turned out to be important to look for pan-crashing words with vowels in as many of the three critical positions (penultimate, ante-penultimate, preantepenultimate) as possible. The reason that the pan-crashing word set decreased from seven to six for words of seven or eight letters was the sudden increase in words of this type: for six-letter words the only all-vowel trigram in boldface type in the Pocket Dictionary was adIEUs, but for seven-letter words the trigrams batEAUX, pitEOUs, serIOUs, bivOUAc, BedOUIn, liqUEUr, requIEm, seqUOia and sinUOUs all appeared. In order to construct a six-word set, it is necessary that three of the words have all-vowel trigrams, and that none of these trigrams crash with each other.

Having constructed pan-crashing word sets for dictionary lists of three through eight letters, it was not too difficult to adapt the method-
ology to find pan-crashing letter sets as well. Here are the best
(minimum number of letters) sets known:

<table>
<thead>
<tr>
<th>Letters</th>
<th>Minimum Number of Letters</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>19 (aeiglops)(aeiortu)(eotuy)</td>
</tr>
<tr>
<td>4</td>
<td>17 (aeiou)(aeiouy)(aeiouy)(i)</td>
</tr>
<tr>
<td>5</td>
<td>22 (aeu)(aeiouy)(aeiouy)(aeiou)(ey)</td>
</tr>
<tr>
<td>6</td>
<td>23 (1)(ir)(aeiou)(aeiou)(aeiouy)(aehy)</td>
</tr>
<tr>
<td>7</td>
<td>22 (1)(a)(aer)(aeiou)(aeiou)(aeiou)(ety)</td>
</tr>
<tr>
<td>8</td>
<td>20 (1)(1)(eu)(aeiou)(aeiouy)(aeiouy)(ey)</td>
</tr>
</tbody>
</table>

These letter sets are not unique; other combinations with the same
total of letters can be found.

What about larger dictionaries? Webster's Collegiate may not be
ever larger than the Pocket Dictionary to furnish a good test of the
effect of dictionary size, but Webster's Unabridged is so large that
hand-searching for pan-crashing sets is extremely hard. (For five-
letter words, a pan-crashing set of size seven has been proposed by
Garry Crum in the May 1972 Word Ways -- AYOUS EOSIN I-HEAD
MIAOU OUIJA SEUGH UAYEB -- but it is uncertain that this has been
thoroughly checked against the Big Web.) Britishers have an advan-
tage in studying the effect of dictionary size, for Chambers Twentieth
Century Dictionary is intermediate in size between Webster's Colleg-
iate and Webster's Unabridged. Kevin Rutherford of Derby, England
has found the following pan-crashing word sets (1972 edition):

aia cay eye IOU Leo ord pin ugh
aery euoi ciao oyos soil taut unce
kleep falty liyar jeton pious quail souse
Alzoon ecurie feodal gaiety noyaus plaint queued
ancanha bedouin dubious faraday pileate thereof unquiet
breivate epopoeia Ghanaian lifebuoy nauseous totalled

Apparently the size of the pan-crashing set does not depend strongly
upon the size of the dictionary. His words possess an added property
not required of pan-crashing word sets: they do not crash each other.

For pan-crashing letter sets, he found:

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<tr>
<td>4</td>
<td>18 (aeiou)(aeiouy)(aeiouy)(i)</td>
</tr>
<tr>
<td>5</td>
<td>24 (aeiouu)(aeiouy)(aeiouy)(aeiou)(h)</td>
</tr>
<tr>
<td>6</td>
<td>24 (1)(aeiou)(aeiou)(aeiou)(aeiou)(eoy)</td>
</tr>
<tr>
<td>7</td>
<td>21 (1)(a)(1)(aeiou)(aeiou)(aeiou)(achly)</td>
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<td>8</td>
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Pan-crashing word sets guarantee a crash between one or more
members of the set and each word in the list. A related, but far hard-
er, problem is to construct a unique pan-crashing word set: one for

which each word in the set must crash with at least one other in the
set, but with none crashing with any of the words outside the set.
that, if the list of words is long, the search for such a set must be a
possible unique

Alternatives for the
beams hard:

Examples for

Suppose, that the small
list can on,

one already

less.

The best Poe

1973 issues:

add bra one

use well

ammo cz

raja

angst blu

oxbow

asthma b

length

188
which each word in the list has a unique crash pattern. For example, if EMBRYO crashes with the first, fifth and sixth words of the set but with none of the others, then no other word in the list is permitted to crash with only the first, fifth and sixth words. It is not hard to show that, if the list has between $2^{n-1}$ and $2^n$ words, a unique pan-crashing set must be at least of length n; however, it is likely that the minimum possible unique set will actually be somewhat larger than this.

Alternatively, one can construct a list of $2^n$ words having a unique pan-crashing set of n words. For example, if n equals three,

beam crashes bake near trim
best bake near trim
mail bake near trim
rose bake near trim
purr near trim
fold

Examples for somewhat larger values of n ought to be possible to construct.

Suppose, finally, that the word list is selectively constructed so that the smallest pan-crashing set is identical with the list; how large a list can one find with this property? This problem is equivalent to one already formulated by Dmitri Borgmann in Beyond Language (Scribner's, 1967): construct a list of mutually non-crashing words.

The best Pocket Webster examples (taken from the May and August 1973 issues of Word Ways) are:

add bra car dew ebb fly gnu hit imp jog nth owl pyx run ski use who
ammo czar etch fizz husk ikon know lynx newt ogle plum raja twig Urdu whys spry yogi
angst bluff copypa drink ethyl fjord gizmo helve ictus lynch oxbow psalm rumba spring them udder wacky asthma blazon cystic embryo freeze guffaw hiccup knobby length madder oblong scruff toward uphill whilst

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