

MTRN2500

7ci fgY[·]Cj Yfj]Yk

GhJZZ 7 cbhJWh 8 YhJ] g

7cbj Ybcfg

B Ua Y	9a U]`	5j U]`UV]`] m	@cWUh]cb	D\cbY
eyc'Ki		D`YUgY`WcbHUWriVm YaU]``hc`aU_Y Uddc]bhaYbhg`k\Yb mci`bYYX	>%+!' \$%7	f\$&Ł'-',) *)(,
		Webgi `HUH]eb"		

@YWhi fYfg

B Ua Y	9a U]`	5j U]`UV]`] m	@cWJhjcb	D\cbY
Ac\UaaUX [.] 8Y[\Uh	- 9	J	,	f\$&Ł'-',)
		Ya U]``hc`a U_Y		%*)\$
		Uddc]bha Ybhgʻk \Yb		
		mci byyx		
		Wcbgi `HJh]cb"		

8Ya cbghfUhcfg

B Ua Y	9a U]`	5j U]`UV]`] m	@cWUh]cb	D\cbY
7Ufc DUbY	WdUbY4 i bgk "YXi "Ui			
8Ub]Y`@UhjaYf	X"`Uhja Yf4 i bgk "YXi "Ui			
8mUb'GUbig]!; c\	X"gUbi g]![c\4 i bgk "YXi "Ui			
?Ybh <i< td=""><td>_Ybh'\i 4 i bgk "YXi "Ui</td><td></td><td></td><td></td></i<>	_Ybh'\i 4 i bgk "YXi "Ui			

K YV

GWXcc`cZA YWXUb]WU`UbX'A Ubi ZUWi f]b['9b[]bYYf]b[

9b[]bYYf]b[Gh XYbhGi ddcfhGYfj]WYg

9b[]bYYf]b['\DXi glf]U\'HfU]b]b[

<u>I BGK "Gh Xm5VfcUX"UbX"91 VX.Ub[Y</u>"flcf"]bVci bX"gh XYbhgŁ

I BGK : i hi fY Ghi XYbhq

D\cbY

fŽ*%'&Ł'-',)',)\$\$'-Bi WYi g'Ghi XYbh<iV

fŽ*%'&Ł'-',)'+**%'-'9b[]bYYf]b['-₺Xi ghf]U`'HfU]b]b[

fŽ*%'&Ł'-',)'' %+-'-'I BGK 'Ghi Xm5VfcUX'UbX'I BGK '9I WXUb[Y'fÆcf']bVci bX'ghi XYbhgŁ

fž*%*&Ł'-',) '(\$-+'-'GWXcc``CZ]WYłł

 $\label{thm:condition} $$H^*D^*UgY^*bchY^*h\Uhih\Y^*GW\&cc^*CZ_J^WY^*k_J^*bch_bck_k^*\Yb\#Zmci_f^*Wci_fgY^*Wcbj_Ybcf^*]g^*cb^*WUa_di_g^*cf_Uj_UJ^*UV^*Y_.$

7ci fgY 8YW] g

7 fYX]hDc]bhg * *

Gi a a UfmcZh\Y'7ci fgY

H\]g`Wci fgY`k]```HYUW\`ghi XYbhg`7ŽŽ`UbX`A Uh`UV`dfc[fUa]b["`H\Y`Z]fgh\\U`ZcZh\Y`Wci fgY`ZcWi gYg`cb`h\Y`YUfb]b[`cZ7ŽŽ`dfc[fUa a]b[`Zcf`A YW\Uhfcb]W9b[]bYYf]b["`8i f]b[`h\Y`gYWcbX`\U`ZcZh\Y`Wci fgYž'h\Yghi XYbhg`UfY`]bhfcXi WXX`hc`A Uh`UV`]b`h\Y`WcbhYI h`cZA YW\Uhfcb]WgmghYa g"

H\Y'Wci fgYg']b'h\Y'A YW\Ulfcb]Wg'X]gW]d`]bY'UfY'Vi]'hi dcb'Zci f'X]ZZYfYbhUfYUg"'H\YmUfY. 'a YW\Ub]WJ'XYg][bž'Wca di h]b[ž'Y`YWfcb]Wg'UbX'a]WfcdfcWfggcfgž'UbX'Wcblfc``gmghYa g"'H\Y'`UlfYf'h\fYY'UfYUg'UfY]bhYffY`UhYXž'UbX'h\]g'Wci fgY'Zcfa g'U'WcfbYfglrcbY'cZh\Y'Z bXUa YbhU`'Wci fgYg'cb'k\]W\'h\Y'A YW\Ulfcb]W 9b[]bYYf]b['dfc[fUa 'UhI BGK ']g'Vi]'h''5'\][\'`Yj Y``cZdfc[fUa a]b['g_]``g']g'bYWfggUfmhc'XYj Y`cd W ghca]gYX']bhYfZJWY fci h]bYg'hc 'Wca a i b]\WhY'k]h\#\cblfc``j Uf]ci g'Y`Ya Ybhg'cZA YW\Ulfcb]WgmghYa g" H\]g'_bck 'YX[Y']g'YggYbh]U``]b'dfc[fUa a]b['Wcblfc``gmghYa g'UbX'XYj Y`cd]b['gcZk UfY'a cXi 'Yg'Zcf'h\Y]bhYfZJW]b['cZj Uf]ci g'\UfXk UfY'YYa Ybhg'hc [Yh\Yf'hc'Zcfa 'Wca d'YhY'A YW\Ulfcb]WGmghYa g"'5g'gi W\ž'h\Y Wcblf]Vi h]cbg'Zca 'h\]g'Wci fgY'hc'h\Y'A YW\Ulfcb]W9b[]bYYf]b['XY[fYY'dfc[fUa 'UfY'UVgc`i hY`mYggYbh]U`"

7ci fgY 5]a g

- &" 8Yj Y`cd cVYWhcf]YbhYX`g_]``g`i g]b['7ŽŽ"
- ' "8YjY`cd]b['cVYWficf]YbhYX'dfc[fUagihc']ad`YaYbhWcblfc``gmghYag"
- ("AU_]b['h\Y'gh'XYbhg'ZJa]`]Uf'k]h\'[YbYfU`'UbX'Z|bXUaYbhU``WcbW'dhg'cZAUhf]l''U`[YVfU'ig]b[AUhUV"
-) " Dfc[fUa a]b['g_]``g'Zcf'a Ulf]l 'a Ub]di `Ulf]cb'UbX'XUlfU'j]gi U`]nUlf]cb'g_]``g'i g]b['A UlhUV"
- *"5dd`]\W\righthjcbg`]b`gc`j]b[`X]\ZYfYbrjU``YeiUrjcbg\zdufrjU``X]\ZYfYbrjU``YeiUrjcbg`UbX`gc`irjcb j]giU`]nUrjcb"

7ci fgY @YUfb]b['Ci hWca Yg

 $52 h Y f g i WW g g \underline{J} ``mW ca d`Yh] b ['h] g `W c i f g Y z 'm c i 'g \ c i `X `V Y `UV `Y 'h c .$

@YUfb]b['Ci hWca Y	95 GW[Y%7ca dYhYbW]Yg
%"'6Y'k Y``'j YfgYX'k]h\'ghfi WhifYX'UbX'acXi`Uf'dfc[fUaa]b['ig]b[7#7DD'UbX'hc'\Uj Y'UddfYW]UhYX'h\Y'igY'cZgcZhk UfY'hc Wcaaib]WUhY'k]h\'YIhYfbU`'XYj]WYg"	D9%"%žD9%" žD9%"*
&"'6Y'UV'Y'ho'i bXYfghUbX'\ck'ho']bhYfZUWY'ho'Ub'YI hYfbU``XYj]WY h\fci[\'U'Wca di hYf'dfc[fUa'ho'YZZYWhWcbhfc`'UWnJcb"	D9&"&
' "'6Y'UV`Y'hc'XYj Y`cd'dfchchmdY'i gYf']bhYfZUWYg'hc'Ugg]ghi]b'h\Y XYj Y`cda YbhcZWcbhfc``YX'A YW\Uhfcb]WgmghYa g"	D9&"&ž [*] D9&"'
("'Hc'\Uj Y'XYj Y`cdYX'U'Z bXUa YbHJ`'_bck `YX[Y'cZh\Y'A UhUV	D9%"&ž'D9%"* ž'D9&"&

@YUfb]b['Ci HWca Y	95 GHJ[Y %7ca dYhYbW]Yg
ZfUa Yk cf_'UbX'hc'\Uj Y'XYj Y`cdYX'U'g_j``hc'WkccgY'UbX'i gY A Uh`UV'hcc`g'hc'gc`j Y'dfcV`Ya g']b'A YWkUhfcb]WUbX']b'ch\Yf	

5ggYgga Ybh

5ggYgga Ybh'HUg_g

5ggYgga Ybh'HJg_	K Y][\h	8iY'8UHY	Gh XYbh@YUfb]b[Ci hWca Yg 5ggYggYX
±bX]j]Xi U``Dfc YWfg`))।	Bch5dd`]WUV`Y	%ž'&ž'' ž'(
HY ghg ·	()	Bch5dd`]WUV`Y	%ž (

5ggYgga Ybh'8YHJ]`g

5ggYgga Ybh% ±0X]j]Xi U`Dfc YWfg

GhUfhXUhY. Bch5dd`]WUV`Y

8YHJ]`g.

H\Y`]bX]j]Xi U``dfcYWfg`]bWi XY`fk c`Ugg][ba Ybfg.`

• 7ŽŽ Ugg][ba Ybhfl)ı Ł

• FYYUgYX: f]XUmK YY_&

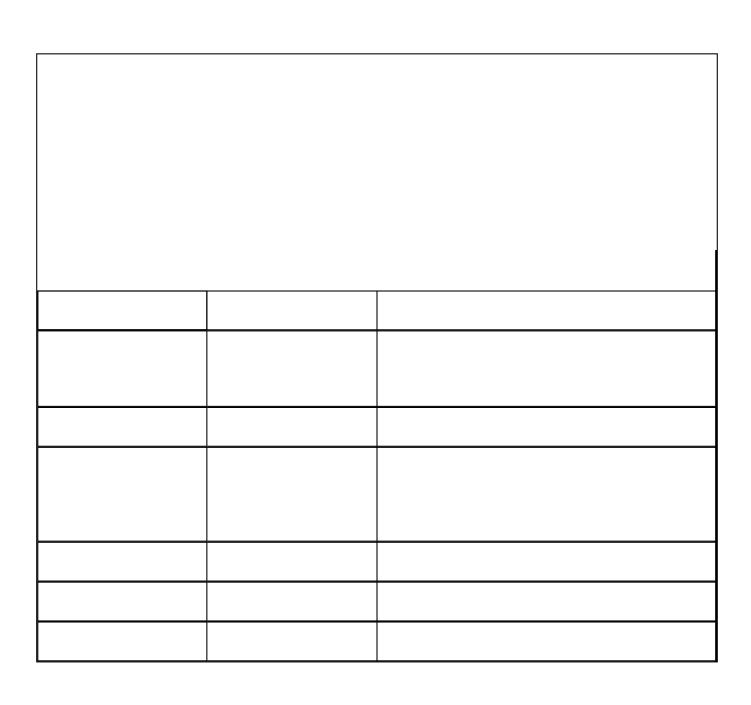
• 8 i Y : f]XUmiK YY_'*

• A Unuv Ugg][ba Ybhf&\$ı Ł

• FYYUgYX: f]XUmiK YY_.,

• 8 i Y :: f]XUmiK YY_'%

Gi Va]gg]cb bchYg.FYZYf hc h\Y Ugg][ba YbhgdYWg"



FYgci fWyg

DfYgWf]VYX F Ygci fWYg

Bch'Uj U]`UV`Y

FYWca a YbXYX FYgci fWYg

Cb`]bY`fYgci fWg'Zcf'7ŽŽ`UbX`A UhUV`dfc[fUa a]b['k]``VY``]b_YX`h\fci [\`A ccX`Y"

7ci fgY 9j U'i Uhjcb UbX 8Yj Y'cda Ybh

: YYXVUW_cb`h\Y`Wci fgY`]g`[Uh\YfYX`dYf]cX]WU``mii g]b['j Uf]ci g`a YUbgž]bWi X]b['h\Y`I BGK a m9l dYf]YbW'`dfcW'ggž]bZcfa U``X]gW gg]cb`]b`h\Y`Z]bU``WUgg`Zcf`h\Y`Wci fgYžUbX`h\Y`GW\cc`'g Gh XYbh#GhUZZa YYh]b[g"'Mci f`ZYYXVUW_]g`hU_Yb`gYf]ci g`mžUbX`Wcbh]bi U``]a dfcj Ya Ybhg`UfY`a UXY`hc`h\Y Wci fgY`VUgYXž]b`dUfhžcb`gi W\`ZYYXVUW_"

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

5ggYgga Ybhgi Va]gg]cb UbX a Uf_]b[Wf]hYf]U

G\ci`X'h\Y'WcifgY'\UjY'Ubmbcb!Y`YWfcb]WUggYgga Ybh'gi Va]gg]cbž'h\YgY'g\ci`X'\UjY'U'ghUbXUfX GW\cc`'WcjYf'g\YYh'

5```gi Va]gg]cbg`UfY`YI dYWYX`lc`VY`bYUh`UbX`WYUf`mgYhci h'`Mci f`fYgi `hg`UfY`h\Y`d]bbUWY`cZU```mci f`\UfX k cf_'UbX`g\ci `X`VY`lfYUh'X`k]h\`Xi Y`fYgdYWf'`DfYgYbh]b[`fYgi `hg`WYUf`m[]j Yg`h\Y`a Uf_Yf`h\Y`VYghW\UbW' cZi bXYfgHUbX]b[`mci f`a Yh\cX/Yj Yb`]Zh\Y`bi a Yf]WU``fYgi `hg`UfY`]bWcffYWf

A Uf_]b['[i]XY`]bYg`Zcf`Ugg][ba Ybhgi Va]gg]cbg`k]```VY`dfcj]XYX`Uhh\Y`gUa Y`h]a Y`Ug`Ugg][ba YbhXYhU]`g hc`Ugg]ghk]h\`a YYh]b['UggYggUV`Y`fYei]fYa Ybhg"`Gi Va]gg]cbg`k]```VY`a Uf_YX`UVWcfX]b['hc`h\Y`a Uf_]b[[i]XY`]bYg`dfcj]XYX"

@UhY 'dc`]Wh

 $\label{thm:condition} $$HY^UHY'dYbU'mm]g'Udd']YX'dYf'WUYbXUf'XUmf]bWi X]b['k YY_YbXg'UbX'di V']W\c`]XUmgŁ'h\Uh'h\Y UggYgga Ybh']g'cj YfXi Y'''H\YfY']g'bc'dfc!fUhU'cZh\Y''UhY'dYbU'mmZcf'gi Va]gg]cbg'a UXY'dUfhk Umh\fci [\'UXUm'$

 $\label{eq:conversion} \text{K cf_'gi Va]} \text{httx:'UZhtf:h.Y:'XYUX`]bY:'Zcf:'UVgc`i htt:'ZU]'':]g'bchUWWtdhtx:'UbX:'U'a Uf_'cZ'nYfc'k]```VY'Uk UfXYX Zcf:'h.Uh'UggYgga Ybh']hta " } \\$

: cf`gca Y`UggYgga Ybh`]hYa gž`U``UhY`dYbU`hma Umbch`VY`Uddfcdf]UhY"`H\YgY`UfY`WYUf`m`]bX]\WUhYX`]b`h\Y Wci fgY`ci h`]bYž`UbX`gi W\`UggYgga Ybhg`fYWY]j Y`U`a Uf_`cZnYfc`]Zbch`Wca d`YhYX`Vmh\Y`gdYWJZJYX`XUhY" 9I Ua d`Yq`]bWi XY.

%" K YY_`mcb`]bY`hYghg`cf``UVcfUhcfmk cf_`k cfh\`U`ga U```dfcdcfh]cb`cZh\Y`gi VYWha Uf_žcf &" C b`]bY`ei]nnYg`k \YfY`Ubgk Yfg`UfY`fY`YUgYX`hc`gh XYbhg`cb`Wca d`Yh]cbžcf

- ' "DfcZYgg]cbU``UggYgga Ybh'hUg_gž'k\YfY`h\Y`]bhYbh]cb`]g`hc`WfYUhY`Ub`Ui h\Ybh]WUggYgga Ybh'h\Uh\Ug`Ub`UVgc`i hY`gi Va]gg]cb`XUhYžcf
- ("DUgg# U] UggYgga YbhHJg_g"

91 Ua]bUh]cbg

Mci 'a i gh'VY'Uj U]`UV`Y'Zcf'U```ei]nnYgž'hYghg'UbX`YI Ua]bUh]cbg": cf'Wci fgYg'h\Uh\Uj Y'Z]bU``YI Ua]bUh]cbgž h\YgY'UfY'\Y`X'Xi f]b['h\Y'I b]j Yfg]hmYI Ua]bUh]cb'dYf]cXg.': YVfi Ufm'Zcf'Gi a a Yf'HYfa ž'A Um'Zcf'H\ž 5i [i gh'Zcf'H\&ž'UbX`Bcj Ya VYf#8 YWYa VYf'Zcf'H' "

D`YUgY'j]g]ha m BGK 'Zcf'Dfcj]g]cbU``91 Ua]bUh]cb'h]a YhUV`Y'di V`]g\'XUhYg": cf'Z fh\Yf']bZcfa Uh]cb'cb Yl Ua gž'd`YUgY'gYY'h\Y'<u>91 Ua g</u>'k YVdU[Y"

GdYWJU`7cbg]XYfUhJcb

⊋mci `\Uj Y`YI dYf]YbW/X`Ub`]``bYgg`cf`a]gUXj Ybh fY`VYmcbX`mci f`Wcblfc``h\Uhk]```]bhYfZYfY`k]h\`mci f

UggYgga YbhidYfZcfa UbWYžmci 'UfY'Y`][]V`Y`hc'Udd`m'Zcf'GdYWJU``7cbg]XYfUhJcb'df]cf'hc'gi Va]htjb['UbUggYgga Ybhicf'g]htjb['Ub'Yl Ua"

: cf`XYhJ]`g`cZUdd`m]b['Zcf`GdYW]U``7cbg]XYfUh]cb`UbX`WcbX]h]cbg`Zcf`h\Y`Uk UfX`cZgi dd`Ya YbhUfm UggYgga Ybhž'd`YUgY`gYY`h\Y`]bZcfa Uh]cb`cb`I BGK 'g`<u>GdYW]U``7cbg]XYfUh]cb`dU[Y</u>"

D`YUgY'bchY'h\Uhghi XYbhg'k]``bch'VY'fYei]fYX'hc'dfcj]XY'Ubm'XcW'a YbhUfm'Yj]XYbWY'hc gi ddcfh'UVgYbWg'Zfca 'Ubm'WUggYg'a]ggYX'**VYWUi gY'cZ'7CJ=8!%** 'di V`]W\YU'h\ 'a YUgi fYg'gi W\'Ug]gc`Uh]cb"'| BGK 'k]``bch'VY']bg]gh]b['cb'a YX]WU`'VW'fh]ZJWUh'Yg'Zfca 'UbmcbY'XYYa YX'hc'VY'U'dcg]h]j Y'WUgYZ cf'k\Yb'h\Ym\Uj Y'fYWcj YfYX"'Gi W\'WYfh]ZJWUh'Yg'UfY'X]ZZJW 'hhc'cVhU]b'UbX'di h'Ub'i bbYWYggUfmghfU]b'cb ghi XYbhg'UbX'a YX]WU`'ghUZZ''

5 WUXYa]W<cbYglmUbX D`U[]Uf]ga

 $\label{thm:continuous} I BGK ``Ug`Ub`cb[c]b[`Wcaa]ha Ybhhc`ZcghYf]b[`U`W`hi fY`cZ`YUfb]b[`]bZcfa YX`VmUWUXYa]W]bHY[f]hm'`5``I BGK ``ghi XYbhg`\Uj Y`U`fYgdcbg]V]`]hmhc`UX\YfY`hc`h\]g`df]bW]d`Y`cZUWUXYa]W]bHY[f]hm'`D`U[]Uf]ga i bXYfa]bYg`UWUXYa]W]bHY[f]hmUbX`]g`bchhc`YfUhYX`UhI BGK "`B'$Y[$de_ SfG@EI [e VWX]`WW Se ge[`YfZWi adVe ad [VWSe aXafZWde S`V bSee[`YfZW_ aXXSe kagdai`ž$

Mci 'UfY'U'gc'fYa]bXYX'h\UhWUfYZ ``h]a Y'a UbU[Ya Ybh']g'Ub']a dcffUbhdUfhcZgh XmUbX'cbY'cZh\Y]XYbh]Z]YX'WUi gYg'cZd`U[]Uf]ga ']g'dccf'h]a Y'a UbU[Ya Ybh''Gh XYbhg'g\ci `X'U``ck 'gi Z]W]Ybh'h]a Y'Zcf fYgYUfW\ž'XfUZh]b['UbX'h\Y'dfcdYf'fYZYfYbW]b['cZgci fWYg']b'dfYdUf]b['U``'UggYgga Ybh'lUg_g''

⊋d`U[]Uf]ga `]g`Zci bX`]b`mci f`k cf_'k \Yb`mci `UfY`]b`Z[fghmYUfžmci f``YWi fYf`k]```cZYf`mci `Ugg]gHUbWY`hc]a dfcj Y`mci f`UWUXYa]Wg_]``g"`H\Yma UmUg_`mci `hc``cc_'Uhgca Y`cb`]bY`fYgci fWYgž'UhhYbX`h\Y`@YUfb]b[7 YbhfYžcf`gca Yha Yg`fYgi Va]hmci f`k cf_'k]h\`h\Y`dfcV`Ya `Z|I YX"`<ck Yj Yf`a cfY`gYf]ci g`]bghUbWYg`]b`Z[fgh

5 WUXYa]W = b Zcfa Uh cb

7 fYX]hdc]bhg

7 ci fgY'WfYX]h']g'WU'W'`UhYX']b'I b]hg!C ½7 fYX]hfl C 7 L'''H\Y'bcfa U``k cf_`cUX'YI dYWfUhJcb'Zcf'cbY'I C 7]g'UddfcI]a UhY`m'&) '\ci fg'dYf'hYfa "'H\]g']bWi XYg'WUgg'WcbhUWh'\ci fgz'df]j UhY'ghi Xmz'ch\Yf'`YUfb]b[UWfj]]h]Ygz'dfYdUfUhJcb'UbX'hJa Y'gdYbh'cb'U``'UggYggUV`Y'k cf_"

A cgh'Wci fgYk cf_'Wci fgYg'Uhl BGK 'UfY'*'I C 7 'UbX']bj c`j Y'Ub'Ygh]a Uh'X'%) \$`\ci fg'hc'Wca d`YhY'''9UW\ Wci fgY']bWi XYg'U'dfYgWf]VYX'bi a VYf'cZ\ci fg'dYf'k YY_'fl\#\ Ł'cZgW\YXi `YX'ZJ\W!hc!ZJ\W''UbX#cf'cb`]bY WcbhJ\Wi'5bmUXX]h]cbU``h]a Y'VYmcbX'h\Y'dfYg\fy]VYX'WcbhJ\Wi\ci fg'g\ci `X'VY'gdYbh]b'a U_]b['gi fY'h\Uh mci 'i bXYfghJbX'h\Y''YWfi fY'a UhYf]U'ž'Wca d`Yh]b['h\Y'gYhUgg][ba Ybhgž'\Z fh\Yf'fYUX]b[ž'UbX'fYj]g]b['Zcf UbmYl Ua]bUh]cbg"

Cb!WUa di g WUgg UHYbXUbW

Di V`]WX]ghUbW]b[`WcbX]h]cbg`a i ghVY`Zc``ck YX`Zcf`U```H' `ZUWY!hc!ZUW'`WUggYg"`Hc`Ybgi fY`h\]gž`cb`m ghi XYbhg`Ybfc``YX`]b`h\cgY`WUggYg`k]```VY`U``ck YX`]b`h\Y`fcca "`7`Ugg`fcghYfg`k]```VY`UhtUW\YX`hc

a dcfhUbh'@]b_g

- A ccX`Y
- <u>@UV:5\W\/aa</u>
- < YU`h\ 'UbX'GUZY m
- <u>7 ca di h|b[: UW|^]h|Yq</u>
- Gh XYbhF Ygci fWg
- 7 ci faY 'C i hlbYa
- 9b[]bYYf]b['Gh XYbhGi ddcfhGYfj]\Wg:7YblfY
- A U YfadUW
- I BGK 'H]a YHUV'Y
- I BGK '< UbXVcc
- LBGK 'A YWXUb]WU`'UbX'A Ubi ZUWi f]b['9b[]bYYf]b[
- <u>9ei]hUV`Y`@YUfb]b[`GYfj]WYg</u>

a U[Y'7fYX]h

GmbYf[]Yg^]b^GcibX^&\$%*

7F = 7CG

7F = 7CG Dfcj]XYf 7cXY. \$\$\$-,;

5W_bck `YX[Ya YbhcZ7ci blfm

 $K Y : UW\underline{b}ck `YX[Y : h, Y : 6YXY[U : dYcd `Y : k \c : UfY : h, Y : hfUX]h\underline{b}cb U ``W ghcX]Ubg : cZh, Y ``UbXg : cb : k \] WX : I B G K ? Ybg]b[hcb : WUa di g :]g ``c WUhYX''$

