!

! "#"\$%&' (%) *#"\$%&\$+% !"#\$%&' (#)*&+,#-./01 2#3 (#4567'819,:55315;1</0,#'7541 9#74'1=#)*>&1?533.@.15;1?#37;5)47#11 A-B-1C5D1E\$FG1 = 5)#@#H1? I1JEFK1 LJMFN10\$P+EQFG1

!''#\$%&'()*

''##\$!	!! !	%&' ('!	!!	!	!) *+,/+01!23!452.+67!"R#74.&6733.H1S35)7/#11
1	1	1	1	1	1	T.!#)'(.4'15;19!.,7#31 < /0,#'7541
1	1	1	1	1	1	9!. ,7#3'*1 I).#&U1 V 7@:1W4,7/.4,.11 1
1	1	1	1	1	1	T7ܷ'7.&H1?3#&&)55(1#4/11
1	1	1	1	1	1	C.:#675)1 = #4#@. (.4'HIA5&7'76.1C.:#675)11
1	1	1	1	1	1	W4'.)6.4'754&1#4/190!!5)'&H1<;;.,'76.11
1	1	1	1	1	1	W4&')0,'7541
''##''!	!!	8 '96'	!!	!	!) *+,/+01!23!:2.0&!452.+67H!Y#,Z&546733.H11
1	1	1	1	1	1	S35)7/#1
1	1	1	1	1	1	

2 A e C P ec D ec c PD C PDD A Sa Ма C e e f Ca f а D ab U f ed Sc М D С Ca f a C Teac G a f A ea Sc S ec a Ed ca Teac e ASSET Peaa Р а AWARDED

2

</0/3,78*%7:1=1:1/0*

!

!

96+02./&+F!

<3., '. / 1#&1?5+</7'5)IL e 7':1T)-1\7 (1[#4/)0 (NILMGPG+MGP\$N15;1>)?.+5">)3167. (!"':.1 !)#, '7'754.)1"50)4#315;1':.1?504,731;5)1?:73/).41b7':1C.:#675)#31T7&5)/.)&+1T767&75415;1 ':.1?504,731;5)1<D,.!'754#31?:73/).4-1

%@P5+B70+2*/!

(a))(&<)67)A)5"B./(+19*"

?55!.)HIY-\-HIR#@.HI`-II-HI**?50-.I!%'Q'**HI [#A533#HI9-1 = #,90@#+R#@.HII-If19,5''HI\-=-1 LMGPQN-1</0,#'5)&1&.3;+).!5)'./1')#7474@HIO&.1#4/1!.),.76./1.;;.,'76.4.&&15;1 .67/.4,.+X#&./1,3#&&)55(1(#4#@.(.4'1!)#,'7,.&-1@()6)+,7+2":=3..9"8179/()!" *C#*LPNHIP\$+ME-1

1

? 50-.I!%'Q'1 f 1V#*/54H1\-1LMGPKN-1?:#)#,'.)7&'7,&15;1.;;.,'76.1,3#&&)55 (1)03.&U1 I 1).67.b1 5;1':.137'.)#'0).-10)1=3)("D5/=1,7.+!":')=719"D5/=1,7.+"

?501!%'Q' ILMGPMNIV.3!74@1&'0/.4'&1b7':1.(5'754#31#4/1X.:#675)#31/7&5)/.)&1&536.1 (#':.(#'7,&1b5)/1!)5X3.(&-1@()6)+,7+2":=39"8179/()HIFOLPNHIFF+OE1
: ? 50I!%'Q' HIC)5b4HI<-\-HI f 1A*3.HIY-1LMGPPN-1I 1&')#'.@*+X#&./174'.)6.4'7541'517(!)56.1 (#':1!)5X3.(1&53674@1&Z733&15;1&'0/.4'&1b7':1.(5'754#31#4/1X.:#675)#31/7&5)/.)&HI D5/=1,7.+"1+5"0()1,G)+,".H" - 3795()+"LELENIF\$F+FFG-1
[#4/.)&HI<-HI9.)6735HI2-I ?50I!%'Q' IfIV#*/54HI\-ILMGPPNIV7@:3*1gO#37;7./I'.#,:.)I).gO7).(.4'&1;5)I&!.,7#31./O,#'5)&UIT.7474@1/7&).&!.,'UIII)O)#31'.#,:.)&>I !.)&!.,'76.HI (19":')=719"D5/=1,7.+"M/1(,)(9?!"\$GLMNHIP\$+PQ-1</td
9,5''HI\-9-HI ?50I!%'Q' I f IV7)4HI c-ILMGPPN-I I 41.D# (74#'754I5;1'*!7,#31,3#&&)55 (1,54'.D'I #4/174&')0,'754I;5)I&'0/.4'&Ib7':1#4/1b7':50'IX.:#675)#31/7&5)/.)&-ID5/=1,7.+" I+5"0()1,G)+,".H" - 3795()+!"LELENIOPJ+0EP-I
9,5''H1\-=H1 ?501!%'Q' 1f1=,_0733#4H12-lLMGPGN-lS04,'754#3lX.:#675)1#&&.&&(.4'U19,#374@1/5b41'51&,#3.10!H1N+,)(6)+,7.+"7+":= $39"1+5"-97+7="ECLMN1QK+JE-1$
$\begin{array}{l} 9,5''\text{H} \setminus - = -\text{H} ?501!\%'Q'\text{H} c 5\&.4X.) @\text{H} = -1 f 1C5)@(.7.)\text{H} ?-1LMGPGN1T.,7&754+(#Z74@1741&.)6.4'754\&.54/#)*1#4/1'.)'7#)*174'.)6.4'754&15;1&.553b7/.174'.)6.4'754&15;1&5&7'76.1&.X.:#675)1&0!!5)'-1D5/=1,7.+"1+5"O()1,G)+,".\text{H}" - 3795()+!"LLLENH1FP$+F$O-1&.1&+"Complexity" and the second seco$
[#4/.)&HI<-1 f1 ?50I!%'Q' ILMGGQN-19'0/.4'&>1,:#33.4@74@1X.:#675)1#4/1'.#,:.)&>1"5X1 &#'7&;#,'754-1>)?.+5">)3167.(HIPQLPNHIMO+\$\$-1
$\begin{array}{l} \textbf{?50I!\%'Q'1?54)5*H1 = -I - H1 = \#4,73H1R-c-1 f 1V\#*/54H1 - 1LMGGQN-1 I 1,5 (!#)7&54H5;1 \\ \textbf{;04, '754\#31X.:#675)1\#\&\&.\&\& (.4'1 (.':5/535@7.\&1b7':1*504@1,:73/).4U1T.\&,)7!'76.1 \\ (.':5/\&1\#4/1;04, '754\#31\#4\#3*&7\&-1B./(+19".H">)3167.("D5/=1,7.+"%0!"MGG+MPJ-1 \\ \end{array}$
? 501!%'Q -H1 e *)7, ZH1 I -H1C)5 b 4H1<- \-1 f 1 [74@5H1 I -9-1LMGGQN-1W (!)5674@1 (#':. (#'7, &1 !)5X3. (1&53674@1&Z733&1;5)1&'O/.4'&1b7':1,:#33.4@74@1X.:#675)&-1>)?.+5">)3167.(1 %OL\$NH1M+K-1
$= #4,73 \text{HIR-c-HI}?54)5* \text{HI} = - \text{I-HI}?501!\%'\text{Q-1} f1^* #Z#5 \text{HI} - \text{ILMGGONISO4}, '754 #31?5 ((047, #'7541 ()) #7474@1741': .14#'0) #31.467)54 (.4' UI I 1!735'1746.&'7@ #'7541 b7': 1#1*504@1, :73/1b7': 1 #0'7& (1&!.,')0 (1/7&5)/.) -1D5/=1,7.+"I+5"0()1,G)+,". H" - 3795()+!"#PHIOPF+0$E-1$
C5*/HIC-I-1?54)5*HI = 1 = #4,73HIR-c-HI` #Z.5HI -1 f 1?50I!%'Q'ILMGGON-1<;;.,'&15;1,7),0 (&,)7X./174'.).&'&1541':.1&5,7#3IX.:#675)&15;1,:73/).41b7':1#0'7&(-1B./(+19".H" 4/,7*G"1+5"Q)6)9.'G)+,19"Q7*.(5)(*!"LOLQNHIPFFG+PFOP-1]
TO43#!HIR-HI?3#)Z.HI9-HI?54)5*HI = -I - I f 1?50I!%'Q'!

C5*/HIC-I-HI**?50-.I!%'Q**-HI f1?54)5*HI = -I-ILMGGEN-II]&74@1':.7)174'.).&'&UI I1/7;;.).4'I &')#'.@*1;5)17(!)5674@1':.1&5,7#31&Z733&15;1*504@1,:73/).41b7':1I0'7&(-1>)?.+5" >)3167.(-1%EHI\$+J1

!

O)S, T...U''

- 9,5''H\\-=-HII4/.)&54HI?-HIf1**?50-.I!%'Q'**ILMGPPN-1*V1+127+2"-91**(..G">)3167.("W*7+2"* @.*7,76)">)*3167.(":/''.(,RI*[54@(54'H]?BUI95!)7&-1
- !
- >..U"=31',)(*"
- ?54)5*H1 = -I -H1?50-.I!%'QH1 f 190':.)3#4/H12-ILMGPEN-1?3#&&)55 (+X#&./174'.)6.4'7541).&.#),:1741':.1;7.3/15;1<CTU1?0)).4'1!)#,'7,.&1#4/1;0'0).1/7).,'754&-1W41A-1 R#)4.)H1Y-12#0;; (#4H1 f 1Y-1<3375'1L</&N-1X1+5T..U".H"DG.,7.+19"1+5" >)3167./(19"Q7HH7=/9,7)*ILM!"1./7'754NIL!!-EOF+EKQN-1[54/54U19#@.-1

1

 $\begin{array}{l} ?54)5^{*}\text{H} = -I -\text{H} ?50^{-} .I!\%'Q'IIC5^{*}/\text{H}C^{-}I f 1C . ''747\text{H}<-1LMGPEN-1 \ .\#, : .)1') . !#)#'7541;5)1 \\ \& '0/.4'\&1b:51/.(54\&')\#'.1, :#33.4@74@1X.:#675)\&-1W41A^{-}1974/.3#)\text{H}<-T^{-}I \\ = , ?)#^{*}\text{H} = - (-1C)5b4.33\text{H} f 1C^{-}I[74@40@#)7\&^{2})#;'IL</&-N^{-}IX1+5T..U''.H''<)^{*})1(=3'' .+'': ')=719''D5/=1,7.+''O)1=3)(''@()'1(1,7.+''L!!^{-}I) \end{array}$

11

1

? 50-.I!%'Q'!LMGPON-1?:#)#,'.)7&'7,&15;1<;;.,'76.1?3#&&)55(1c03.&U|I1c.67.b15;1':.1[7'.)#'0).-1 \.#,:.)|</0,#'5)&15;1?:73/).41b7':1C.:#675)|T7&5)/.)&H\\.(!.H|Ii-1

?50-.1!%'Q'! f 1?55!.)HIY-ILMGP\$N-10)1=3)(*Z"W*)".H"DHH)=,76)"V1+12)G)+, "@(1=,7=)*Y":/(6)?7+2" HIG7971(7,?"1+5")S')(7)+=)-1\.#,:.)1</0,#'5)&15;1?:73/).41b7':1C.:#675)1T7&5)/.)&H1\.(!.HIIi-1)

? 50-.1!%'Q'HI e #3Z.)HIY-1 f 1 [#4/.)&H<-1LMGP\$N1 [31," - 3199)+27+2">)3167. (*"Q. "0)1=3)(*"N5)+,7H?" $I*"@()619)+,"I+5"@(.T9)G1,7=RIPG^{\$}$ 1 440#31W4'.)4#'754#31?54;.).4,.1541A5&7'76.1C.:#675)1 90!!5)'-19#41T7.@5H!? I -1

!

1

1

? 50-. I!%'Q'!LMGP\$N-1*DS1G*7+7+2"()91,7. +*37 '*"*T*),*A*))+"*,/5)+,"=3199)+27+2"*T*)3167. /("1+5",)1=3)(" \. *T*"*1,7*H1=,7. +*R*1PP^{#\$}1 I 440#31V#b #771W4'.)4#'754#31?54;.).4,.1541</0,#'754-1V5453030H1VW-1 1

? 50-.I!%'Q'ILMGP\$N-1-9*1***(..*G*&*T1**)*5*"N+,)(6)+,7.+"<)*)*1*(=*3*"7+",*3*)"87)95".H"*D*>*Q*Y"-/(()+," @(*1*=,7=)*"*1*+5"8/,/()"*Q*7()=,7.+*-IPP[#]\$I I 440#3IV#b#77IW4'.)4#'754#3I?54;.).4,.1541 </0,#'754-IV5453030HIVW-1

 $\begin{aligned} \textbf{?50-.I!\%'Q'H19,5''H1} &= -1 \text{ f } 1?55!. \textbf{)} \text{HY-ILMGPMN-1} - 91^{**}(...G\&T1^*)5^{"7}+, \textbf{)}(6) + \textbf{,7.+}^{"}()^*\textbf{)} 1(=3^{"7}+",3)^{"} \textbf{H7} \textbf{)} 95^{"} \\ . \texttt{H}^{"}D &> QY^{"} - /(()+, "'(1=,7=)^{*"}1+5^{"} \textbf{H}/, /()^{"}57()=,7.+^{*}-1 \ ... \texttt{H}, :..) 1 < /0, \texttt{H}'5)\&15; 1?:73/). 41b7': 1C.: \texttt{H675} \textbf{)} \\ T7\&5)/.)\&-1 \ . (!.\texttt{H} \text{ I } i-1 \end{aligned}$

? 50-.I!%'Q'ILMGPMN-1 [31, "=3199)+27+2"T)3167. (*"5.",)1=3)(*"75)+,7H?"1*"G.*,"'()619)+,"1+5" '(.T9)G1,7=R1 \.#,:.)1</0,#'5)&15;1?:73/).41b7':1C.:#675)1T7&5)/.)&H1 \.(!.HIIi-1]

? 50-.I!%'Q'ILMGPPN-1-*3199*)+27+2"*T*)*316*7. ("*I*+5",)*I*=3)("\. *T*"**1*,7*H*I*=,7. +*Y*"*V*12+7,/5)"*I*+5" '()*61*9)+=)"*I**"=(7,7=*1*9"H*I*=,.(*RI \.#,:.)I</0,#'5)&15;I?:73/).41b7':IC.:#675)IT7&5)/.)&-1 \.(!.HI I i-1)

?50-.I!%'Q'!LMGPGN-10)1=3)(",(17+7+2",."7G'(.6)"*,/5)+,*Z"A7,3"D>Q"')(H.(G1+=)".+"G1,3"A.(5"

? 50-. I!%'Q-l f 19,5''H\-=-lLMGGJN8/+=,7.+19">)3167. ("4**)**G)+,Y" [3)+"<)*)1(=3!" @.97=?"1+5"@(1=,7=)"-.9975)!1=7/b.&'19*(!5&70(1541[.#/.)&:7!1;5)IC.:#675)IT7&5)/.)&-12#4&#&1?7'*H=B-1

1

1

? 50-.I!%'Q-HI [74@5HI I -9-HIS.4'*HI ` -9-I f 1V7)4HI c -1LMGGJN-1*Q*)6)9. '7+2"*V*1,3"89/)+=?"7+" :,/5)+,*"*A*7,3" - 3199)+27+2">)3167. (HO^{#\$}1W4'.)4#'754#31?54;.).4,.1541A5&7'76.1C.:#675)1 90!!5)'-IY#,Z&546733.HIS [-1

?50-.I!%'Q'HI ?54)5*HI = -I -I f 19,5''H\-=-IL`56. (X.)HIMGGQN-18/+=,7.+19"4**)**G)+,"1+5":,/5)+,*"A7,3"D>QY" [3)+"<)*)1(=3!"@.97=?"1+5"@(1=,7=)"-.9975)-1\$M

1

? 50-. I!%'Q'HI [74@5HI I -9-1 f 1S). *HI I -1LMGGKNR"@(. 2(1G&A75)"@>: "7+"D1(9?" - 37953..5" :),,7+2*Y"NG'9)G)+,17.+"1+5"V)1*/()G)+,"_/=.G)*-1?504,731;5)1<D,.!'754#31?:73/).41 I 440#31?546.4'7541#4/1<D!5&7'754HI [507&6733.HI 2 h 1

1

? 50-.1!%'Q'I12.((.).)HI [-1 f 1 = #4,73HIR-c-ILI !)73HIMGGKNR"NG'(.67+2"8/+=,7.+19">)3167.(" 4^{**})**G)+,*Y"-.G'1(7+2"Q)*=(7',76)"4**)**G)+,"V),3.5.9.27)*"A7,3"8/+=,7.+19" 4+19?*7*

:.=719">)3167.(*".H"-3795()+"A7,3"4/,7*GRIA).&.4'./1#'1':.1T767&7541;5)1<#)3*1?:73/:55/1 #'1':.1?504,731;5)1<D,.!'754#31?:73/).4-1A5)'3#4/HIB).@54-1

 $\begin{array}{l} \label{eq:constraint} \label{eq:cons$

1

? 50-. I!%'Q'I f 1? 54)5*HI = - I - IIL = #*IMGGFN-11D+67(.+G)+, 19"4((1+2)G)+, *"1+5"b7*/19" :/''.(,*"0."@()6)+, "@(.T9)G">)3167.(R1IA).&.4'./I#'1':.1I//).&&74@1?:#33.4@74@1C.:#675)+1`#'754#31\)#7474@1W4&'7'0'.1541<;;.,'76.1A)#,'7,.&190!!5)'74@1h504@1?:73/).4>&195,7#3^1<(5'754#31T.6.35!(.4'H1?3.#)b#'.)IC.#,:HIS35)7/#-1

? 50-.I!%'Q'1 f 19,5''H\\-=-lLS.X)0#)*IMGGFN-14"<)67)*A*".H"8/+=,7.+19">)3167.(" 4**)**G)+,*c">)3167.("N+,)(6)+,7.+"@91+*"H.("DG.,7.+19c>)3167.("Q7*.(5)()5":,/5)+,*" 7+"1"89.(751"@/T97=":=3..9":?*,)GRI1=7/b.&'19*(!5&70(1;5)1[.#/.)&:7!1741C.:#675)1 T7&5)/.)&-l12#4&#&HI ?7'*HI = 7&&50)7-1

1

 $C5^*/\text{HIC-I-HI}?50-.1!\%'Q'1f1?54)5^*\text{HI} = -I-11LT...(X.)\text{IMGGEN-18}/+=,7.+19"4^{**})^{**}G)+,"1+5" N+,)(6)+,7.+".H":.=719":U799^*\text{"H.}("^./+2"-3795()+"A7,3"4/,7^*GR11A).\&.4'./1#'1T767&7541;5)1 <#)3*1?:73/:55/1#'1':.1?504,731;5)1<D,.!'754#31?:73/).4-1?:7,#@5H1W337457&-1$

C5*/HC-I-H?54)5*H = -I-HIf1?50-.I!%'Q'HL`56.(X.)HGGEN-HW*7+2",3)"<)*,(7=,)5"

?50-.I!%'Q'ILS.X)0#)*HIMGGQN-I#*I*":,(1,)27)*"H.("*V*1+127+2"-3199)+27+2">)3167.(R190!.)75)1 R)..4&'54.IT7&')7,'19,:5531C5#)/HI = #)#':54HIB`HI?#4#/#-1

?50-.I!%'Q'!LT.,.(X.)HIMGGKN-1:=3..9&A75)":?*,)G*".H"@.*7,76)">)3167.(":/''.(,Y"O)1G"

?50-.1!%'Q'ILMGGKNI *V1+127+2",3)">)3167.(".H"-3795()+"A7,3"4/,7*G-*IY.;;.)&541?504'*1 AOX37,19,:553&-1[507&6733.H2 h1

>/,=17/*

1												
DS,)(+19""												
MGPP1<3.,'./1'51 7'5)7#31C5#)/15;1)3167.(19"Q7*.(5)(*1												
MGPG1<3.,'./1'51 7'5)7#31C5#)/15;10. '7=*"7+"D1(9?" - 379535": ')=719"D5/=1,7.+1</td												
c.67.b.)+l	.67.b.)+1 A).6.4'74@19,:5531S#730).1											
	Y50)4#315;1A5&7'76.1C.:#675)1W4'.)6.4'754&1											
1 1	\5!7,&1741<#)3*1?:73/:55/19!.,7#31 0,#'7541</td											
1 1	$C_{.:}$ #675)1 T 7&5)/.)&1											
N+,)(+19"												
9#74'1=#)*>&1?533.@.+11												
MGP\$+MGPK11	1	1	1	1	1	W4&'7'0'754#31c.67.b1C5#)/11						
1 1	1	1	1	1	1	L?:#7)H1MGPF+MGPKNH11						
MGPO+MGPJ1	1	1	1	1	1	I,#/.(7,19.4#'.						

• S.335b&:7!1). !).&.4'74@1':.1:7@:.&'1@)#/0#'.1&'0/.4'1#b#)/1!)567/74@1#1 ;0331;50)1*.#)&15;1&0!!5)'1':)50@:1#14#'754#33*1,5(!.'7'76.1&'7!.4/1#4/1;0331 '07'7541b#76.)-1

A#)'4.)&1 741 T5,'5)#31 A).!#)#'754U1 I1]47;7./1 [.#/.)&:7!1 A)5@)#(1741 <#)3*1 ?:73/:55/19!..7#31</0,#'7541#4/19,:5531A&*,:535@*H"W+76)(*7,?".H"89.(7511

1 1 1 • I1;./.)#33*1;04/./1M+*.#)1!)5@)#(1!)567/74@1;033+'07'754H1&'7!.4/H1#4/1 @)#/0#'.1#&&7&'7!.1